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Biology 30

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ell Division, Genetics, and Molecular Biology

Unit C

Cell Division:
The Processes of Mitosis and Meiosis

Module 5

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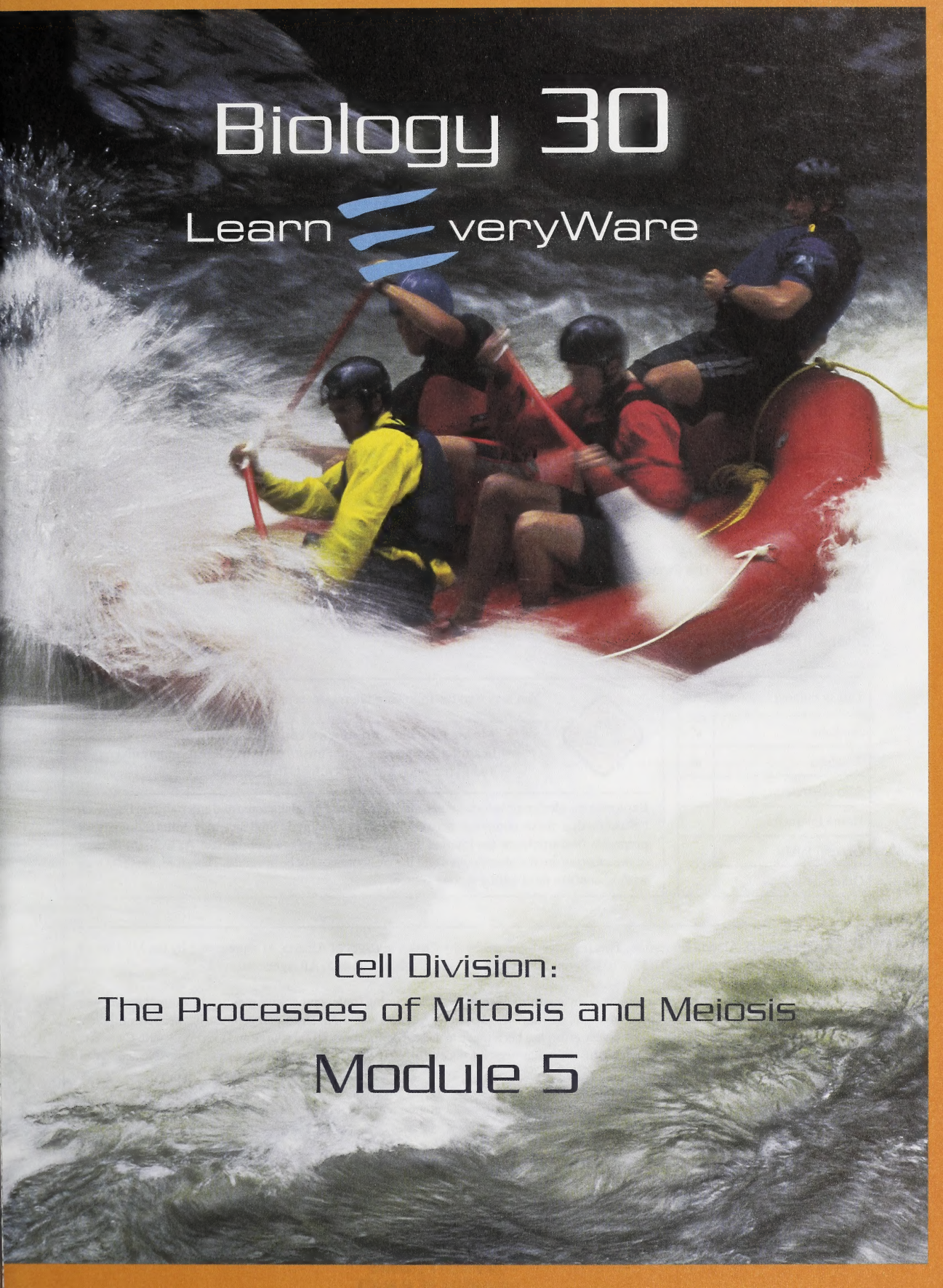
Biology 30
LearnEveryWare
Cell Division:
The Processes of Mitosis and Meiosis
Module 5

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Module 5: Cell Division: The Processes of Mitosis and Meiosis
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Unit C Introduction

From one generation to the next, from single cell bacteria to people, all are part of a competition to create more individuals of our own species. How do we ensure our best is passed on to the next generation? Now that science has discovered most of the mechanics of the process of inheritance, a new question is arising: should we now manipulate inheritance to suit our whims? Should we have the power to decide exactly what the next generation will look like?

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This unit is all about the cycle of life. From the secrets of cellular reproduction, to the story of why you may have your grandmother's nose, this unit will explore how your biology is caught in an increasingly complex drive to survive on a changing planet.

In Unit A you examined how the human body uses the nervous and endocrine systems to maintain homeostasis. In Unit B you examined closely how the human reproductive system ensures the continuation of the species. In Unit C you will examine the mechanisms of reproduction at the cellular level, the principles deterring the inheritance of characteristics, and the mechanism of transmitting the genetic code from one generation to the next.

There are three modules in Unit C:

- Module 5—Cell Division: The Processes of Mitosis and Meiosis
- Module 6—Mendelian Genetics: The Transmission of Traits to the Next Generation
- Module 7—Molecular Genetics: DNA, RNA, and Protein Synthesis

In Module 5 you will examine reproduction at the cellular level. Individual cells, like humans and all other multi-cellular organisms, need to ensure the next generation has all that it needs to survive and excel. In human reproduction, you saw how this creates a cycle as one is born, grows, mates, and gives birth to the next generation. In a similar way, cells follow a life cycle of growth, preparation, and division. In this module you will learn how the cell life cycle naturally progresses. You will examine how cells copy their instructions for the next generation. You will also discover how cells divide to form new, complete cells or divide to form incomplete cells that must find another cell with which it will join in order to become a new, whole organism. You will compare these methods of reproduction, examining their advantages and limitations. As you work through this module, you will begin to realize just how important the regulation of the cell cycle is as you consider cancerous or "wild" cell growth.

In Module 6 you will come to understand that the instructions copied by cells during the cell cycle code for traits observed in organisms. You will look more closely at how an organism passes on his or her traits to the next generation. As you consider these patterns of inheritance, you will learn about the works of Gregor Mendel and Thomas Morgan, and how they contributed to our understanding of genetics today. You will practise using predictive tools that will allow you to understand and explain the movement of hereditary traits, including disease and conditions, through a family pedigree.

In Module 7 you will examine the molecular basis for these traits in the cell, and you will gain an understanding of how cells express these traits through protein synthesis. As you examine the molecules present in our cells, you will reflect on how mutation can change the intended expression of our genetically inherited traits. Genetic change can result in disease. It can also result in enhanced abilities, and can be the basis of evolution as explored in Unit D.

Following are the major concepts you will explore and the skills you will develop in this unit:

- Explain the rules and steps involved in mitosis and meiosis that regulate the transmission of genetic information from one generation to the next.
- Describe the similarities and differences that exist in mitosis and meiosis that allow for growth, healing, and reproduction of organisms.
- Hypothesize how the understanding of the molecular nature of genes and DNA can help explain the transmission of traits, and how mutation at the molecular level results in changed proteins.
- Analyze how the knowledge of the molecular nature of genes and DNA has led to new biotechnologies and treatment of genetic disorders.

Think about the following questions as you complete this unit:

- What are the cellular processes that an organism uses for growth, healing, and reproduction to ensure the survival of his or her species?
- What regulates the transmission of genetic information from one generation to the next?
- How is DNA responsible for the production of proteins?
- How has the molecular knowledge of genes and DNA led to new biotechnologies and the treatment of genetic disorders?

As you work through this unit, you may go to the McGraw-Hill Ryerson online learning centre at **www.albertabiology.ca**.

As you work through the three modules of this unit, there will be self-checks, labs, lesson assignments, module assessments, and a unit assessment. Pieces for assessment will be clearly identified for submission to your teacher. All course work should be stored in your course folder.

Unit C is 40% of the Biology 30 course and should take approximately 50 hours to complete.

Before you begin the unit assessment, you may wish to do the review questions on pages 668–671 in your textbook, or you may consult with your teacher as to which of these questions it would be appropriate for you to answer. Or, if you have contact with your peers in this class, create a study group of two to four people. Within your group, complete the questions in the text or those suggested by your teacher. Each member in the group should save a copy of your completed answers to your course folder.

Submit a copy of your work to your teacher. If you are working independently, review your responses with your teacher. If you have formed a study group, once every group has submitted its response, your teacher will post an answer key to the discussion area or class website. Compare your group's answers to those in the answer key. If you are unsure about a particular question, please contact your teacher.

When you have completed this unit, complete the following Unit Assessment and submit your work to your teacher.

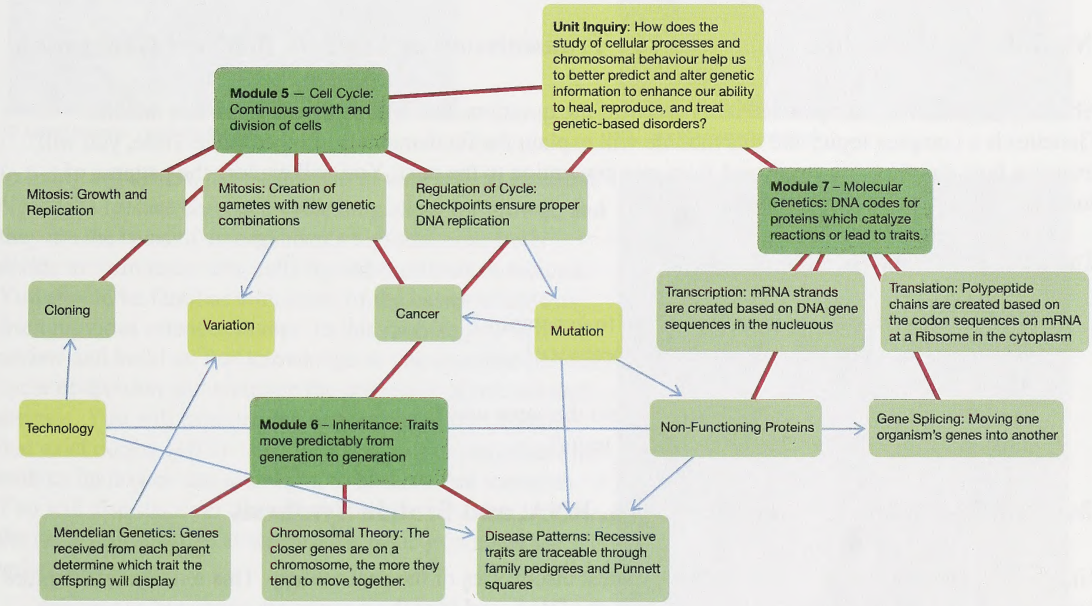
Unit Assessment

Common across all modules in this unit is the idea of natural or desired life patterns and exceptions to these patterns that result in disruption or disease. For the module assessment, you will look in detail at breast cancer. You will need to consider how tumour cells have deviated from the natural cell cycle, how the inheritance of certain genes can increase the likelihood of developing this cancer, and how specific mutations in other regions of DNA ultimately lead to the initiation of cancerous growth. When you are ready to begin the unit assessment, go to the Unit Assessment section for instructions and a rubric indicating how the written response will be marked.

Unit C Concept Organizer

The concept organizer below shows the relationship between the cell cycle, patterns of inheritance, and molecular genetics. A properly functioning cell cycle is needed for DNA to be correctly duplicated and divided into new cells for the next generation. This generation will express traits based on logical patterns of inheritance that can be understood by careful observation and recording. These traits are a result of the proper creation of proteins from the genes found on DNA.

The chart below organizes the main ideas of each module. You may wish to create your own chart by using the following chart as a starting point and adding additional detail as you go through this unit. There is an opportunity to prepare a concept organizer in each of the modules that you will study in this unit. Go to the multimedia DVD to view a larger version of the concept organizer that you can print.



Module 5—Cell Division: The Processes of Mitosis and Meiosis

If you scratch your arm or cut your finger, you will be glad to see your skin heal over the wound. What would happen if that regrowth did not stop? How do our cells know when to live, die, or replace themselves? This module will explore the cell life cycle, the production of somatic cells, the formation of gametes, and the reproductive strategies of various species. This module will also look at how scientists use their understanding of the cell cycle to combat cancer and aging.

The following questions will be explored:

- Is there a life cycle clock common to all organisms?
- What are the different ways cells reproduce?
- What are the purposes of reproduction?
- What are the sources of variation or consistency in cell division?

Module 6—Mendelian Genetics: The Transmission of Traits to the Next Generation

Should you look like your parents? This is one of the questions that will be discussed in this module. Genetics is a complex topic, and this module will explain the fundamentals of inheritance. Here, you will examine how simple traits are passed from one generation to the next. You will explore the patterns of inheritance that can be traced and predicted.

The following questions will be explored:

- How are traits passed on from generation to generation?
- What controls an organism's physical appearance?
- Are all genes the same?
- Does the inheritance of traits always happen the same way?
- Can technology change the inheritance of traits?

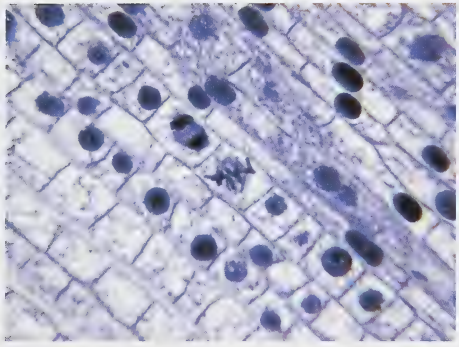
Module 7—Molecular Genetics: DNA, RNA, and Protein Synthesis

Unravelling the code of life was one of the greatest discoveries of the past century. This module will explore how traits are coded by genes that are carried in our DNA, and how these genes are expressed as proteins. This module will also look at how scientists can manipulate these genes or transfer them from one organism to another, resulting in variations never before possible.

The following questions will be explored:

- How does DNA carry the genetic code?
- How does DNA direct the synthesis of proteins?
- What changes in the genetic code result in mutations and variations?
- How much of my genetic code is uniquely mine? Do I share any part of my DNA code with my relatives?

Introduction



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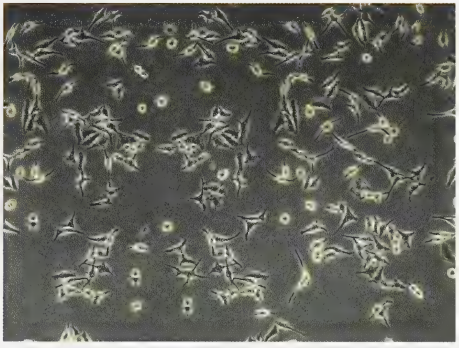

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In living organisms, the production of new cells is essential. New cells replace damaged cells, they allow for growth, and they are the basis of an organism's reproduction. Cells divide to form more new cells by either mitosis or meiosis. You should be familiar with some of the basics of mitosis from previous science courses. In this module you will review and build on that knowledge as you examine the cell cycle of division and compare the processes of mitosis and meiosis. You will examine the opportunities for variation that exist during cell division, and you will become familiar with technologies that allow you to observe that variation. You will also discover that although organisms don't all use the same reproductive strategies, the basic principles are universal.

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Just like any biological process, cell division has its complications. Cancer is an example of mitotic cell division gone wrong. Cancerous cells divide at an uncontrolled rate, causing an abnormal mass of cells. In this module you will further develop your understanding of cell division and how it applies to growth, healing, and reproduction to ensure the survival of species.

In the Biology 30 Course Introduction, several resources, including *The Key* and *Student Notes and Problems Workbook: Biology 30*, were recommended to you for additional support towards your success. Continue to use these resources as you work through Module 5.

Big Picture

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This module is about cycles. Our body cells all follow a cycle. No doubt, somewhere in your childhood, you skinned your knee or cut your finger. Once the tears were done and the bandage was applied, you were probably told it would eventually heal. Over time, our cells are constantly growing and dividing to replace what is old or damaged. Skin cells can replace themselves every three days. Cells of the digestive tract and respiratory tract replace themselves rapidly because of the damage they experience from everyday use. Muscle cells are much slower to replace, and bones can take months to heal.

Our life is part of a cycle too. In the previous unit you studied in detail how human life begins. In this module you will learn how other organisms may follow similar or very different patterns in reproduction. As you consider your own family, everyone is at a different stage in their life cycle, and so are the cells within their bodies.

What would happen if we could step outside of one of these cycles? What would it be like to get our cell lines to stop growing older? What if they could grow and reproduce at the same rate, throughout our lives, as when we are twenty years old? Aside from the social implications, there could also be very serious biological implications to consider. Cancer cells are in essence our own body cells that no longer respect the cell cycle. They reproduce as quickly as they can and never stop. Clearly, cancerous cells are not the target of the anti-aging industry! As you continue through this module, think about the internal clock that regulates your cell reproduction and aging.

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As you explore healthy and unhealthy or uncontrolled cell cycles, you will focus on the big question of how cellular processes allow for growth, healing, and reproduction in the support of the survival of living organisms.

This module will explore the following focusing questions:

- What structures pass genetic information on to the next generation, and in what ways can cells ensure this information is passed on successfully?
- What are the stages and phases of the cell cycle, and do these change with age?
- How do meiosis and mitosis compare in the creation of new cells?
- When is consistency desired over variation, and which processes ensure the proper outcome?
- What differences exist between fraternal and identical twins?
- How do chromosome disorders occur, and why does their occurrence increase with age?
- What are the advantages or disadvantages of different reproductive strategies?

This module relies on prior knowledge of the cell and how it works. If you feel you need to review the concepts of the cell before you begin this module, read pages 546 and 547 in your textbook. If you are comfortable with your knowledge of the cell, continue on with the module.

To help you organize the concepts you learn in Module 5, and to provide you with a study aid for review before you complete the Module Assessment, you may choose to download the Module 5 Concept Organizer from the multimedia DVD. Fill in this concept organizer with the ideas you master as you work through each lesson, or prepare the organizer when you have completed Module 5. You can use keywords, point form, or any amount of detail that meets your needs. You may choose to work from the file on your computer, print the document and work from the paper copy, or copy the outline onto a large sheet of poster paper. The concept organizer provided outlines some of the key topics that you should include in each lesson of your concept organizer. This is a great tool to review and use for study purposes, but using this organizer is completely your choice.

Your Module Assessment will involve the application of your knowledge about normal growth, repair, and reproduction in cells and organisms; consideration of exceptions to normal patterns; and evaluation of their impact. When you have completed all the lessons, you will need to complete one of the Module Assessment task options. For further details about the Module Assessment and the evaluation criteria, visit the Module Assessment section.

In This Module

Inquiry Question: How do cellular processes allow for growth, healing, and reproduction in supporting the survival of organisms?

There are six lessons in Module 5.

Most of the lessons are designed to take 80 minutes to complete; however, some lessons may take longer because of the significance of the concept being covered in the lesson. The suggested lesson times do not include the time needed to complete such activities as "Try This," "Watch and Listen," assignments, practice questions, review, or research.

Module 5 in Unit C corresponds to Chapters 16 to 18, or pages 546 to 671, in your textbook. Before you begin your comprehensive study of the lessons, you may wish to read Chapter 16, pages 546 to 583, for an overview.

Lesson 1: Cell Division and Chromosomes

In this lesson you will identify types of cellular division and understand the function and purpose of each. You will be able to recognize the structures within the cell that carry genetic information. You will learn about the significance of chromosome number in cells and learn how to read a picture of human chromosomes.

In this lesson the following focusing questions will be examined:

- What kinds of cell division exist and when do they occur?
- What are the structures that pass genetic information on to the next generation, and how are they observed?

Lesson 2: The Cell Cycle and Cancer

In this lesson you will learn to identify the phases of the cell cycle. You will learn how a normal cell regulates this cycle and how some cells can exit the cycle or may even ignore these clues.

In this lesson the following focusing questions will be examined:

- What are the stages and phases of the cell cycle?
- Do all cells have the same ability to reproduce, and does this change with age?

Lesson 3: Mitosis

In this lesson you will learn to describe the stages of mitosis. You will learn why this type of growth is important and how new daughter cells compare to their parent cell.

In this lesson the following focusing questions will be examined:

- How are the phases of mitosis identified and described?
- How does mitosis maintain consistency in plants and animals?

Lesson 4: Meiosis

In this lesson you will learn to describe the stages of meiosis. You will come to understand when meiosis is necessary and how it differs from mitosis. You will learn the major sources of genetic diversity and why it is important to a species.

In this lesson the following focusing questions will be examined:

- How does meiosis contribute to genetic variation?
- What differences exist between fraternal and identical twins?

Lesson 5: Cell Cycle Disorders and Genetic Testing

Cell reproduction does not always proceed as planned. In this lesson you will learn of common disorders resulting from improper cell division and you will be asked to consider the ethical issues involved in prenatal testing and working with embryonic cells.

In this lesson the following focusing questions will be examined:

- How do chromosome disorders occur, and why does their occurrence increase with maternal age?
- How can embryonic cells be used, and what technologies exist to test the genetic condition of an unborn fetus?

Lesson 6: Variation in Reproductive Strategies

In this lesson you will learn about the wide variety of reproductive strategies found in different organisms. You will also gain an appreciation for the variety of ways species balance their life cycles.

In this lesson the following focusing questions will be examined:

- What are the advantages or disadvantages of different reproductive strategies?
- Why do some organisms vary their reproductive strategies?

Module 5—Cell Division: The Processes of Mitosis and Meiosis

Lesson 1—Cell Division and Chromosomes

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Get Focused

Life is about cycles. At the cellular level, the **cell cycle** involves reproducing identical cells through **mitosis**, which results either in the replacement of cells or the growth of a structure. At the organism level, mitosis can also produce identical cells, resulting in more offspring. Organisms with variations are produced through another type of cell cycle called **meiosis**. The similarities and differences in the offspring can be explained by examining **chromosomes**.

As far as the human race is concerned, **genetic material** from both the male and female are necessary to create a new human being. The inheritance of characteristics of either parent continues through the cycle of cellular division and reproduction. The human reproductive cycle is a strictly sexual affair.

Sometimes in nature, reproduction can be rather diversified and unique. Aphids, for example, all hatch out of their eggs as females. Perhaps more alarming is the fact that they already have live nymph aphids developing inside them. These too will be born female and pregnant. Very quickly, aphids can dominate a crop and cause serious economic damage. This sounds like a winning reproductive strategy.

cell cycle: the period of time between one cell division and the next; consists of interphase, mitosis, and cytokinesis

mitosis: cell division that results in identical cells; used for growth and repair of organisms

meiosis: cell division that results in cells that have half the normal chromosome number (haploid gametes); also called reduction division

chromosome: a thick, rod-shaped body in the nucleus that forms when chromatin (long, stringy DNA) supercoils around balls of histone proteins in prophase of mitosis and meiosis

genetic material: DNA; contains the genes that direct the synthesis of proteins needed by the cell; exists as chromatin or chromosomes

Why have males? However, the aphid's tale is not over. In the fall, the cycle changes and males are born. They mate with females and produce eggs that will hatch over winter. Why the change? Why would aphids go through all the trouble of changing strategies just when conditions are getting tougher?

In this lesson you will identify the types of cellular division and reproduction, and understand the function and purpose of each. You will be able to recognize the structures within the cell that carry genetic information. You will learn about the significance of chromosome number in cells, and learn how to read a picture of human chromosomes.

In this lesson the following focusing questions will be examined:

- What kinds of **cell division** exist and when do they occur?
- What are the structures that pass genetic information on to the next generation, and how are they observed?

cell division: the period of the cell cycle where the cell is actively dividing; composed of mitosis and cytokinesis stages

Module 5: Lesson 1 Assignment

Your teacher-marked Module 5: Lesson 1 Assignment requires you to submit a response to a lab on human **karyotype** for assessment. You may choose to do Option A or Option B for this lab.

You will receive instructions on how to complete this assignment later in the lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all of the questions and place those answers in your course folder.

karyotype: a pictorial representation of all the chromosomes of a cell arranged in homologous pairs according to size, centromere position, and banding pattern; used to diagnose abnormalities in chromosome number (non-disjunction) and to determine sex chromosomes

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Required Materials and Equipment

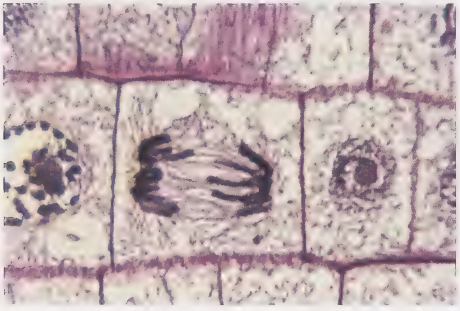
- scissors, glue, and tape
- speakers or headset for audio

Explore

Read

To review some of the structures and the organization of cells that will be useful to you in this unit, read pages 546 to 547 and pages 550 to 552, up to "Chromosome Number," in your textbook. Note the diagram on page 547 of the textbook, or play "Cellular Pursuit" (access from the multimedia DVD) on your own or with a friend as a way to review the different parts of a cell. From this reading or the game, create a glossary of terms needed in this unit. Include **parent cell**, **daughter cell**, **DNA**, chromosome, **histones**, **chromatin**, and **centromere**.

You will recall from earlier science courses that life does not spontaneously occur. Instead, life comes from existing life and is organized around small units called cells. The first part of the cell theory was proposed by two German biologists, Mathias Schleiden and Theodore Schwann. Based on their observations, they concluded that all plants and animals were made of cells. This conclusion has been extended to include all living things and, since their discoveries, no exceptions have been found. Particles such as viruses and prions are technically excluded from the list of "living things."



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parent cell: a diploid somatic cell about to enter cell division

daughter cell: a cell that is the product of cell division

In mitosis, daughter cells are identical to the mother cell; in meiosis, they are not identical to the parent cell.

DNA: the genetic material found contained in the nucleus in eukaryotes (also in mitochondria and chloroplasts) and loose in the cytoplasm in prokaryotes, such as bacteria

histones: proteins found in chromosomes that provide scaffolding for DNA to twine around so that the DNA can fit within the confined space of the nucleus

chromatin: long fibres containing DNA, small amounts of RNA, and proteins

These fibres form chromosomes when they coil around histones.

centromere: a 'button' that holds the two identical sister chromatids together after the S phase of interphase and through mitosis until anaphase

Types of Cell Division

The continuity of life from one cell to another is based on the reproduction of cells via cell division and occurs as part of the cell cycle. There are two major types of cell division: mitosis and meiosis.

Mitosis

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Mitosis is simple cell replication. It begins with one parent cell and ends with two complete daughter cells, which are nearly identical to the original. If the cell being considered is a unicellular organism, then this kind of division is also a form of reproduction known as **binary fission**. Mitotic division in multicellular organisms is responsible for growth, development, and repair. To review why organisms must grow through cell division and not by increasing cell size, read page 550 of the textbook and consider "Figure 16.1" illustrating surface area to volume ratio.

Some multicellular organisms can also reproduce through mitosis under special conditions. This is called **asexual reproduction** since it involves only one parent. Taking a **cutting** from a plant or cutting a flat worm in half are good examples. Some insects can also use this method to rapidly populate an area, like aphids that are born pregnant with more female aphids that will also be born pregnant!

The advantage of mitosis is in speed and energy costs. Only one cell is needed to start and from that many thousands of cells can result. This is why some bacterial infections can spread so rapidly. The disadvantage of this kind of replication is that daughter cells are genetically identical to the parent cell. Therefore, little or no **variation** exists in the population, and it may be susceptible to changes in the environment, such as the use of drugs to treat bacterial infection. However, some bacteria **mutate** very rapidly and develop a **resistance** to drugs. These are termed the **super bugs**, and they are a major concern in the medical community. In Unit D you will study the factors that determine whether or not a population is successful at surviving.

binary fission: cell division in prokaryotes (bacteria); simple because there is only one circular chromosome so no spindle is needed

asexual reproduction: creation of a new organism without the input of cells from two separate organisms of opposite sexes; examples are binary fission, yeast and Hydra budding, and vegetative propagation of plants

cutting: type of vegetative propagation when a stem of a plant is cut off and produces roots, stems, leaves, and flowers; an asexual form of reproduction

variation: the existence of many combinations of genes/traits in a population; improves the probability that some members will survive if environmental conditions change; is high in sexual reproduction

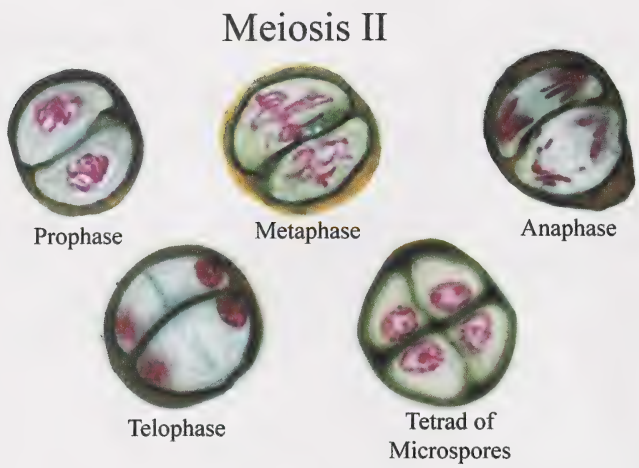
mutation: a permanent change in a cell's genetic structure, often resulting in the expression of a new trait or feature in the affected organism; usually due to random errors occurring during DNA replication or protein synthesis, but can also be caused by chemical or physical mutagens

resistance: occurs when a drug removes susceptible bacteria or viruses from a population and leaves those variants (mutants) that are resistant to the drug

Rapid cell division ensures that the whole population becomes resistant quickly.

super bugs: bacteria that are immune to many antibiotics

Super bugs develop because of an overuse of antibiotics and antibacterials that have destroyed susceptible bacteria, leaving only those bacteria that are resistant to these drugs.



Courtesy of the National Center for Biotechnology Information/National Institutes of Health

Meiosis

Meiosis is a more complex process. After a meiotic division, the resulting cells will have half the needed genetic information. These cells are called **gametes**. To complete replication, a gamete from one parent will need to unite with a gamete from another parent to restore the complete amount of genetic information. This is a process known as **fertilization**, which occurs during **sexual reproduction**.

gametes: sex cells (sperm and egg); have half the normal chromosome number so they can participate in fertilization

fertilization: fusion of an egg and sperm (gametes) to produce a zygote; occurs in sexual reproduction only

sexual reproduction: creation of offspring through input of genetic material from two different organisms of opposite sexes (sperm from male and egg from female); increases variation

While meiosis takes longer, involves more than one parent, and costs more energy to carry out, it does result in variation. By encouraging genetic variation in a population by using meiosis and fertilization, a species will be better suited to overcome change in the environment. Variation increases the chances for survival of a species and increases the chance that members of a population will reach reproductive age so that adaptive traits can be maintained in the population.

Genetic Material

The hereditary material carried by a cell is determined by the genetic code found on **DNA** (deoxyribonucleic acid). DNA is organized inside our body cells into segments called chromosomes. For most of a cell's life, these segments of DNA are diffuse and cannot be observed under a microscope. However, when the cell undergoes division, the chromosomes condense and become visible. For more detail on the organization of chromosomes, read pages 551 and 552 in the textbook.

Every organism has a specific number of chromosomes in its cells. For example, human cells have 46 chromosomes, while dog cells have 78 chromosomes. This number must be maintained from generation to generation for normal function to occur. Chromosomes can be further organized into **homologous chromosomes**. Homologous chromosomes are roughly the same size and shape and contain the same type of genetic information.

In each **somatic cell** of a human body there are 22 pairs of homologous chromosomes, known as **autosomes**, and one pair of **sex chromosomes**. The sex chromosomes determine the gender of the organism. A human with two **X chromosomes** is female, and a human with one X and one smaller **Y chromosome** is male. Read "Chromosome Number" on pages 552 to 553 in the textbook to learn more about chromosomes and how they are arranged in cells. You may choose to summarize this information as a glossary of terms. Include **gene**, **locus**, **allele**, **diploid**, **haploid**, and **polyploid** as terms in your glossary, as you will need to know their meaning as you work through this unit.

gene: the unit of hereditary information that can be passed on to offspring; includes the specific DNA sequence encoding or regulating the sequence of a protein, tRNA, or rRNA molecule; determines the expression of a trait

locus: a specific location on a chromosome

allele: a different form of the same gene occurring on homologous chromosomes

diploid: the term describing a cell that contains two pairs of every chromosome

haploid: the term describing a cell containing half the chromosomes that a diploid parent cell contains

This condition occurs in gametes, either in the egg or the sperm.

polyploid: the term describing a cell that contains more than two homologous chromosomes

somatic cell: the name given to any of the cells of a multicellular organism, including humans

The exception is those cells that form gametes, which are not somatic cells.

autosomes: the 22 homologous pairs seen in a karyotype; have nothing to do with gender

sex chromosomes: the last (twenty-third) pair of chromosomes seen in a karyotype that determines the gender of an organism

X and Y sex chromosomes are not homologous to each other in terms of shape, size, or genetic information.

X chromosome: the longer sex chromosome

Females are XX.

Y chromosome: the shorter sex chromosome; determines maleness; has much fewer genes on it than the X

Males are XY.

Karyotype

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An individual's chromosome set is known as their karyotype. The set, or number and arrangement of chromosomes, is very important for the result of regular life function. Scientists can make a picture of an individual's chromosome set by **staining** cells that are about to undergo cellular division because this is when the chromosomes are most dense. At this point, the chromosomes can be sorted into homologous pairs by their length, position of the centromere (a region of the homologous chromosome pair that appears pinched in), and **banding pattern**.

When sorted, scientists can determine the gender of an organism and whether or not an abnormal number of chromosomes is present. Certain major syndromes are a result of too many or too few chromosomes because chromosomes did not separate equally during cell division. This is termed **nondisjunction**. In humans, **Down syndrome** is a result of an extra chromosome 21 and **Klinefelter syndrome** is a result of an extra sex chromosome (XXY). Read "Examining Chromosomes: The Karyotype" on page 553 of your textbook.

staining: a technique used in slide preparation to make the chromosomes of a dividing cell visible and dark

nondisjunction: an error in meiosis that results in non-separation of chromosomes; results in two chromosomes entering one gamete; produces gametes with an extra chromosome ($n + 1$), or gametes that are missing a chromosome ($n - 1$)

Down syndrome: typically characterized by some impairment of physical growth, unique physical features, and below average cognitive ability

If an $n + 1$ gamete that results from nondisjunction of a twenty-first chromosome is fertilized by a normal sperm, a Trisomy 21 ($2n + 1$) offspring is produced with Down syndrome.

Klinefelter syndrome: born with primary male sex characteristics but develops female secondary sex characteristics

When an XX egg due to nondisjunction is fertilized by a Y sperm, the offspring (XXY) has Klinefelter syndrome.

Watch and Listen

In Unit B you considered the creation of sperm and eggs and how they unite to start a new human life. You discovered how the zygote undergoes continuous cell division and differentiation to eventually become a new person. This lesson identified the processes of mitosis, for growth and differentiation, and meiosis, for sperm and egg production.

Go to the multimedia DVD and watch the animation "Comparison of Meiosis and Mitosis." Without worrying about the specific steps in either process, which will come in a later lesson, use this video to gain a general understanding of how these processes differ. As you watch the video, answer these questions:

- How does the cell prepare for either type of division?
- What structures are involved during the processes?
- How many daughter cells usually result from meiosis or mitosis?
- How do the daughter cells of mitosis compare with those from meiosis?
- In what ways is mitosis similar to meiosis? How is it different?

Record your thoughts in your course folder.

Try This

It is difficult to observe cell division "in action." However, some tissues in plants or animals are undergoing such rapid growth that observation of that area under a microscope can reveal several cells frozen in a stage of division. A common area to investigate is the tips of roots.

Go to the multimedia DVD and open "Microscope Simulation." Choose "onion root tip, mitosis." Explore this slide under various magnifications. Try to locate cells that are dividing. (**Tip:** Cells that are dividing have condensed chromosomes, so they appear as small dark worms instead of a vague mass.) To record your observation, place the pointer on one dividing cell and take a screen capture. Save your findings in your course folder.

Module 5: Lesson 1 Assignment

For your Lesson 1 Assignment, you will complete a lab. You will have the choice of completing a lab simulation or an investigation from your textbook. Either choice will ask you to complete questions in the Lesson 1 Assignment in the Module 5 Assignment Booklet.

Lab—Modelling a Human Karyotype

A karyotype is the set of chromosomes present in a somatic cell. They are often prepared from pictures of stained chromosomes that just started mitosis (cell division) so that the size, shape, and number of chromosomes can be easily studied. In this simulation you will prepare a human karyotype and answer several questions about it and other prepared karyotypes.

Choose and complete Option A **or** Option B. Discuss your option choice with your teacher before beginning the work.

Problem (Purpose)

To create a human karyotype and analyze the results.

Option A

Materials

For this simulation you will require access to the Internet and a word-processing program to record your results. You will also need the Module 5 Assignment Booklet. You will enter your lab results in the "Observations" section of the Lesson 1 Assignment.

Procedure

Go to the multimedia DVD, and open "Human Karyotyping Simulation."

Locate the "Exploration Guide" by clicking on the "Lesson Materials" link. As you read and follow the instructions, make sure you are able to answer the questions. **Note:** Each time it asks you to click on "Copy Screen," you should do so, and paste the results in the "Observations" section in the Lesson 1 Assignment. You may need to copy the image into a word-processing document, and then attach that document to your Lesson 1 Assignment.

Complete the questions in the "Conclusion" section in the Lesson 1 Assignment.

Option B

Complete "Investigation 16.A: Modelling a Karyotype" from page 554 of your textbook. Your teacher will provide a karyotype for your lab. Place your work, including your karyotype and your answers to all the questions, in the "Procedure," "Analysis," and "Conclusion" sections of the Lesson 1 Assignment.

You will receive instructions later in this lesson about when to submit your assignment to your teacher.

Discuss

Cell division can be dramatic and amazing. From a tiny sperm and egg comes a complete new person. Once a person reaches maturity, however, ther growth and repair are less dramatic—broken bones mend and cuts heal.

In the past, when a person lost a finger or an ear, nothing could be done. That may not be the case now. Regrowth of fingertips has been reported with the addition of ground-up pig bladder (a source of stem cells). Perhaps more amazing is the experimentation with growing human tissue or organs inside other animals.

Use the Internet search terms "mouse, human ear, BBC" and follow the link to the BBC website on "Artificial Liver 'could be grown'" or "Girl may be the first to grow artificial ear." In both of these reports there is a picture of a human ear growing on the back of a mouse for transplant.

As promising as these developments are, they raise many ethical questions. Should scientists be experimenting with tissue or organ regrowth using animals? Discuss this question with your classmates and your teacher in the discussion area.

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Reflect and Connect

Self-Check

Complete the following review questions on cell division.

SC 1. In what three general ways is cell division important to your body?

SC 2. In general terms, compare binary fission to mitosis.

SC 3. Give the main advantage of meiosis and why it is important to populations.

SC 4. Differentiate between chromosome, **chromatid**, and chromatin.

SC 5. What characteristics are common between homologous chromosomes?

SC 6. What can scientists learn from creating a karyotype of a developing fetus?

Check your work with the answers in the Appendix.

chromatid: one-half or one of two threadlike strands into which a chromosome divides during cell division

Reflect on the Big Picture

You have been introduced to the main types of cell reproduction: mitosis and meiosis. Each type is important and has a natural role to play in the cycle of life. Perhaps you have a better understanding of the areas scientists study as they try to discover how to extend life. Certainly at the heart of any new technology or procedure will be the need to ensure the proper number of chromosomes is maintained from one generation of cells to the next, and that they contain all the correct genetic information.

Module 5: Lesson 1 Assignment

Make sure you have completed all of the questions for the Lesson 1 Assignment. Check with your teacher about whether you should submit your assignment now or wait until all of the Module 5 assignments have been completed..

Lesson Summary

During this lesson you explored the following focusing questions:

- What kinds of cell division exist and when do they occur?
- What are the structures that pass genetic information on to the next generation, and how are they observed?

Mitosis and meiosis are the main types of cellular division. Most of what we can see or observe around us are examples of mitotic growth or repair. Perhaps that is because it is fast and accurate. However, in later lessons, as you consider the survival of a species and the changing environmental pressures all life must face, you will soon see the value of meiotic reproduction.

In either type, DNA organized into chromosomes is at the heart of proper cell division. In humans, there are 22 pairs of autosomal chromosomes and a pair of sex chromosomes that determines gender. Together, all 46 chromosomes must be duplicated and then passed on to each new daughter cell for those cells to carry out their roles. Chromosomes can be stained and arranged in a karyotpe so scientists can determine the gender of a young developing fetus and whether or not the fetus will be born with genetic disorders.

Lesson Glossary

Consult the glossary in the textbook for other definitions that you may need to complete your work.

allele: a different form of the same gene occurring on homologous chromosomes

asexual reproduction: creation of a new organism without the input of cells from two separate organisms of opposite sexes; examples are binary fission, yeast and Hydra budding, and vegetative propagation of plants

autosomes: the 22 homologous pairs seen in a karyotype; have nothing to do with gender

binary fission: cell division in prokaryotes (bacteria); simple because there is only one circular chromosome so no spindle is needed

cell cycle: the period of time between one cell division and the next; consists of interphase, mitosis, and cytokinesis

cell division: the period of the cell cycle where the cell is actively dividing; composed of mitosis and cytokinesis stages

centromere: a 'button' that keeps the two identical sister chromatids together after the S phase of interphase and through mitosis until anaphase

chromatid: one-half or one of two threadlike strands into which a chromosome divides during cell division

chromatin: long fibres containing DNA, small amounts of RNA, and proteins

These fibres form chromosomes when they coil around histones.

chromosome: a thick, rod-shaped body in the nucleus that forms when chromatin (long, stringy DNA) supercoils around balls of histone proteins in prophase of mitosis and meiosis

cutting: type of vegetative propagation when a stem of a plant is cut off and produces roots, stems, leaves, and flowers; an asexual form of reproduction

daughter cell: a cell that is the product of cell division

In mitosis, daughter cells are identical to the mother cell; in meiosis, they are not identical to the parent cell.

diploid: the term describing a cell that contains two pairs of every chromosome

DNA: the genetic material found contained in the nucleus in eukaryotes (also in mitochondria and chloroplasts) and loose in the cytoplasm in prokaryotes, such as bacteria

Down syndrome: typically characterized by some impairment of physical growth, unique physical features, and below average cognitive ability

If an $n + 1$ gamete that results from nondisjunction of a twenty-first chromosome is fertilized by a normal sperm, a Trisomy 21 ($2n + 1$) offspring is produced with Down syndrome.

fertilization: fusion of an egg and sperm (gametes) to produce a zygote; occurs in sexual reproduction only

gametes: sex cells (sperm and egg); have half the normal chromosome number so they can participate in fertilization

gene: the unit of hereditary information that can be passed on to offspring; includes the specific DNA sequence encoding or regulating the sequence of a protein, tRNA, or rRNA molecule; determines the expression of a trait

genetic material: DNA; contains the genes that direct the synthesis of proteins needed by the cell; exists as chromatin or chromosomes

haploid: the term describing a cell containing half the chromosomes that a diploid parent cell contains

This condition occurs in gametes, either in the egg or the sperm.

histones: proteins found in chromosomes that provide scaffolding for DNA to twine around so that the DNA can fit within the confined space of the nucleus

karyotype: a pictorial representation of all the chromosomes of a cell arranged in homologous pairs according to size, centromere position, and banding pattern; used to diagnose abnormalities in chromosome number (non-disjunction) and to determine sex chromosomes

Klinefelter syndrome: born with primary male sex characteristics but develops female secondary sex characteristics

When an XX egg due to nondisjunction is fertilized by a Y sperm, the offspring (XXY) has Klinefelter syndrome.

locus: a specific location on a chromosome

meiosis: cell division that results in cells that have half the normal chromosome number (haploid gametes); also called reduction division

mitosis: cell division that results in identical cells; used for growth and repair of organisms

mutation: a permanent change in a cell's genetic structure, often resulting in the expression of a new trait or feature in the affected organism; usually due to random errors occurring during DNA replication or protein synthesis, but can also be caused by chemical or physical mutagens

nondisjunction: an error in meiosis that results in non-separation of chromosomes; results in two chromosomes entering one gamete; produces gametes with an extra chromosome ($n + 1$), or gametes that are missing a chromosome ($n - 1$)

parent cell: a diploid somatic cell about to enter cell division

polyploid: the term describing a cell that contains more than two homologous chromosomes

resistance: occurs when a drug removes susceptible bacteria or viruses from a population and leaves those variants (mutants) that are resistant to the drug

Rapid cell division ensures that the whole population becomes resistant quickly.

sex chromosomes: the last (twenty-third) pair of chromosomes seen in a karyotype that determines the gender of an organism

X and Y sex chromosomes are not homologous to each other in terms of shape, size, or genetic information.

sexual reproduction: creation of offspring through input of genetic material from two different organisms of opposite sexes (sperm from male and egg from female); increases variation

somatic cell: the name given to any of the cells of a multicellular organism, including humans

The exception is those cells that form gametes, which are not somatic cells.

staining: a technique used in slide preparation to make the chromosomes of a dividing cell visible and dark

super bugs: bacteria that are immune to many antibiotics

Super bugs develop because of an overuse of antibiotics and antibacterials that have destroyed susceptible bacteria, leaving only those bacteria that are resistant to these drugs.

variation: the existence of many combinations of genes/traits in a population; improves the probability that some members will survive if environmental conditions change; is high in sexual reproduction

X chromosome: the longer sex chromosome

Females are XX.

Y chromosome: the shorter sex chromosome; determines maleness; has much fewer genes on it than the X

Males are XY.

Module 5—Cell Division: The Processes of Mitosis and Meiosis

Lesson 2—The Cell Cycle and Cancer

Get Focused

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Ponce de Leon, a Spanish explorer, spent years looking for the fountain of youth in a part of North America now called Florida. Of course, he never found it. Imagine what life would be like if there was such a fountain from which to drink! Life would be yours for hundreds of years. Alas, the reality is that human cells last only a little more than one century at best. Why do cells age? Is there a secret to keeping body cells young and vigorous that has not yet been discovered?

In this lesson you will also learn to identify the phases of the **cell cycle**. You will also learn how a normal cell regulates this cycle and how some cells can exit the cycle or may even ignore the phases.

cell cycle: the period between cell divisions; divided into the phases of interphase, mitosis, and cytokinesis; may also be divided into interphase and M phase (mitosis and cytokinesis)

In this lesson the following focusing questions will be examined:

- What are the phases of the cell cycle?
- Do all cells have the same ability to reproduce, and does this change with age?

Module 5: Lesson 2 Assignment

You will receive instructions about how to complete this assignment later in the lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all of the questions and place those answers in your course folder.

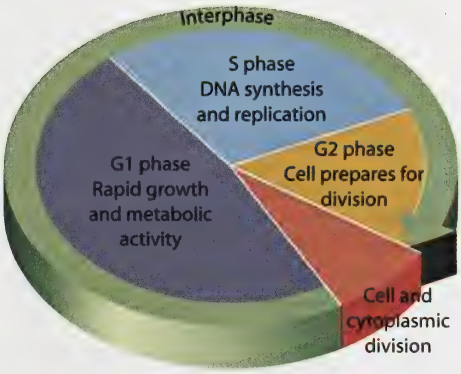
Explore

For approximately 90% of a cell's life cycle, it is not dividing. During this period of the life cycle, the cell performs normal vital activities, such as respiration, photosynthesis, protein synthesis, absorption, secretion, and excretion. Cell division, the remaining 10% of the life cycle, is a process involving a series of stages marking the beginning and end of cell division. Perhaps the most important process preparing for cell division is the **replication** of genetic material in the nucleus. This must be completed before a cell divides so that each daughter cell receives the same genetic complement as the parent cell. Once the replication is complete, the cell is ready to enter the process of division.

replication: the copying of the cell's DNA prior to mitosis so that each daughter cell has an exact copy of the mother cell's genetic material; results in sister chromatids; occurs in the S phase of interphase

Read

Cell Cycle



The cell cycle. Interphase, the stage of growth and metabolic activity, occupies most of the cell cycle. The division stage involves the reproduction of the nucleus and the division of the cell contents.

Inquiry into Biology (Whitby, ON: McGraw-Hill Ryerson, 2007). 553, fig.16.5. Reproduced by permission.

Human bodies are made up of an amazing array of specialized cells that keep them healthy and able to maintain an internal balance in an environment that is constantly changing. During the daily struggle with the environment, cells must be replaced as they wear out. Exactly how fast cells are replaced is related to their role. Skin, which is constantly being scratched, rubbed, or cut, replaces itself very quickly. Muscle or nerve cells may remain healthy for most of a human's life and, therefore, may not need to divide to replace themselves. Some cells, such as red blood cells, which lack a nucleus and genetic material, or gametes, which only have one of each chromosome, will never reproduce.

The typical life cycle of a cell can be broken down into two main phases: **interphase** and **M phase**.

interphase: the longest period of the cell cycle when the cell is actively growing and metabolizing; consists of G1, S, and G2 phases; DNA is in loose, stringy chromatin form not visible under the microscope

M phase: mitosis and cytokinesis together

Interphase is the much longer phase, and is the phase where the cell will carry out its intended function in the body.

M phase, or mitosis phase, is shorter and moves the cell through a complex sequence of steps that are carried out in order to divide the cell's genetic material equally. This phase ends with **cytokinesis**, which is the physical division of the cell into two daughter cells. Read pages 553 to 555 in your textbook to preview the stages of the cell cycle.

Interphase is further broken down into three phases: **G1 phase**, **S phase**, and **G2 phase**.

cytokinesis: the phase of the cell cycle after mitosis when the cytoplasm divides into two separate daughter cells

A cleavage furrow forms in animal cells; a division plate forms in plant cells.

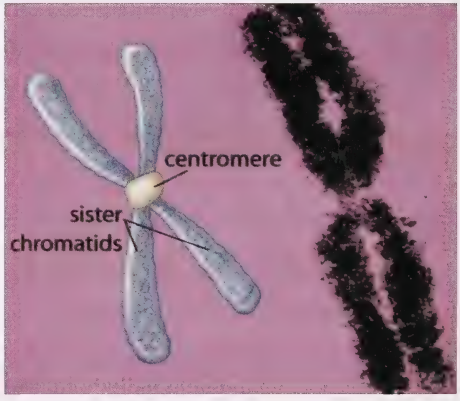
G1 phase: the first part of interphase where the cell is actively growing and undergoing metabolism and protein synthesis

S phase: the second part of interphase where DNA replication occurs in preparation for upcoming mitosis; produces sister chromatids

G2 phase: the third part of interphase where the cell continues growing, metabolizing, and carrying out protein synthesis

During G1, or Growth 1, the cell is growing rapidly, producing proteins and carrying out its intended function. In the case of muscle or nerve cells, they may remain healthy and functioning at this stage for so long that they may be referred to as being "stuck" in G1 or, as it has more recently been referred to, in G0 phase. If, however, this is a regular cell, it will reach a point where it moves on to the S phase.

The G1 stage is critical if the cell is to divide properly later. In S phase, or synthesis phase, the cell will duplicate its DNA exactly. Each single chromosome makes a copy of itself and holds on to the copy. These doubled chromosomes do not contain any new genetic material. Rather, they are identical copies of each other. While together, they are known as **sister chromatids**, and are joined together by a regional structure called the centromere.



Inquiry into Biology (Whitby, ON: McGraw-Hill Ryerson, 2007). 555, fig.16.6. Reproduced by permission.

sister chromatids: two pieces of DNA that are identical to each other as a result of DNA replication in S phase; lie side-by-side and are buttoned together by a centromere; together make up one chromosome

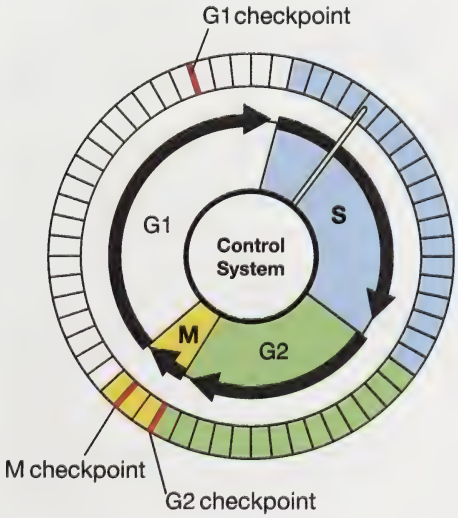
After the DNA has been successfully doubled, the cell will enter G2, or Growth 2. Here the cell continues to carry out its role in the body. Nearing the end of interphase, the cell will get ready for M phase by storing energy and building proteins and other structures needed for cell division.

During M phase, or mitosis phase, the cell will divide each doubled chromosome into two separate single chromosomes. This process will be covered in detail in the next lesson. At this point it should be clear to you that the cell goes through an orderly set of steps necessary to ensure that its genetic material is correctly divided into two complete and equal sets. Following this division, the cell will go through cytokinesis in order to physically divide the cell into two.

Watch and Listen

Go to the multimedia DVD and watch the animation "Control of the Cell Cycle," which brings each stage of the cell cycle together and illustrates how they would typically work in a **eukaryotic cell**. The animation also introduces you to three key checkpoints of the cell cycle: G1, G2, and M checkpoints. While you watch, consider *why* these checkpoints are important and why they occur when they do.

eukaryotic cell: a cell with membrane-bound organelles and nucleus



The animation introduced the checkpoints that regulate division within the cell. These checkpoints ensure that cells are growing and are capable of division.

There are three major checkpoints of the cell cycle. One is at the end of G1. Here, the cell evaluates if it is large enough and strong enough to continue with the division process. The second checkpoint is at the end of G2. This is a very important checkpoint for the cell. At this time, the cell must evaluate if it has properly duplicated all of its chromosomes. If it has not, it may attempt to carry on with the division, or it may simply self-destruct. The last major checkpoint occurs during M phase. At this checkpoint the cell evaluates whether the **spindle apparatus** has properly attached itself to each of the chromosomes, and whether the rest of the cell is ready for cytokinesis, or physical cell division. If something is wrong at this stage, the cell will often simply die.

spindle apparatus: a structure composed of spindle fibres; forms during prophase in mitosis to facilitate separation and movement of chromosomes in cell division

Try This

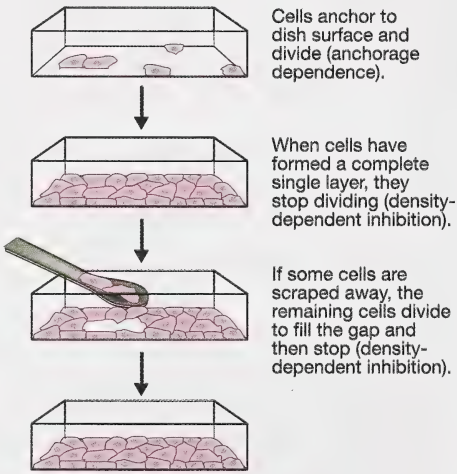
To review the stages of the cell cycle and its checkpoints, do a web search using the search terms "educational games" and "control of the cell cycle." In the activity that you will find, take on the role of Cell Division Supervisor. You will have a limited amount of energy to use for carrying the cell through all of the stages of cell division, as well as to check various cellular components to see if the cell is ready to move on. Try to keep the body healthy!

Read

Reasons and Limits for Cell Growth

There are many factors that may lead cells to reproduce. The most common reason is the need for replacement due to damage or age. Cells work very hard, and many simply become too brittle or build up toxins too fast to continue to function. These cells are broken down by the body, and their raw materials are reused.

Once the call for cell reproduction is given, how do cells know when to stop? Consider skin cells as a working example. Your skin is one of the most active areas on your body for cell reproduction. Skin cells use two common clues to determine when to start or stop reproduction. The first is **density-dependent inhibition**.



(a) Normal mammalian cells

density-dependent inhibition: a property of normal cells that allows mitosis to occur only until cells touch each other

Density-dependent inhibition is lost in cancer cells; therefore, cells begin to form on top of one another, forming masses of cells called tumours.

For density dependent inhibition to work, cells respond to their neighbours. Skin cells will not divide if isolated. If a gap or a cut is created in a layer of skin cells, those that remain will automatically start to divide until the gap is covered. Once skin cells bump up against their neighbours, they stop dividing. The cut is healed.

Another clue that cues cell growth is **anchorage dependence**. Using skin cells again as the example, skin will grow naturally if anchored to a substratum of tissue. Conversely, they will not grow if simply free floating in a nutrient bath. For example, individual skin cells can't be cultured in a nutrient bath, but skin cells anchored in tissue can be cultured to grow in a nutrient bath. These cultures are often used in treating severe burns with skin grafts.

anchorage dependence: a property of normal cells that only allows mitosis to occur when cells are attached to a substrate or surface, not floating freely

Anchorage dependence is lost in cancer cells, thereby allowing for metastasis to occur.

Cancer

The term **cancer** signifies a broad group of diseases characterized by a rapid, uncontrolled division of cells. Cancer cells appear to ignore all the regulations in place for cell growth. They do not wait or stop at any of the checkpoints. They do not appear to be density dependent, nor are they anchorage dependent. Cancer cells grow and reproduce constantly. They never enter the stage of the cell life cycle where specialized function occurs.

cancer: rapid proliferation (cell division) of cells that occurs when mutations result in disruption of the normal timing of mitosis; characterized by loss of density-dependent inhibition, loss of anchorage dependence, dedifferentiation of cell function, rapid metabolism, and short cell cycle

Watch and Listen

Go to the multimedia DVD to watch the following animations:

- "Cancer and the Cell Cycle 1"
- "Cancer and the Cell Cycle 2"
- "Cancer and the Cell Cycle 3"

The first animation shows how a cancerous growth might occur. Another very dangerous characteristic of cancer is shown—its ability to spread. When cancer cells leave their original site, it is called **metastasis**. When cancer cells begin to spread in this fashion through the blood or lymphatic systems, it becomes much harder to get rid of them.

metastasis: the tendency of some cancer cells to break off from a primary tumour and move through the blood or lymphatic systems to other locations in the body where secondary tumours form; sometimes referred to as the "spreading" of cancer

Self-Check

Complete the "Control of the Cell Cycle Questions," which can be accessed from the multimedia DVD.

Watch and Listen

The video "Cell Cycle and Mitosis: Copying the DNA Blueprint" reviews the cell cycle and cancer. Go to the multimedia DVD to watch this video to review or reinforce these concepts and to find information related to the Lesson 2 assignment. Pay particular attention to the end of the video, as it goes over cancer treatments. Watch and listen for information related to the following questions:

radiation treatment: cancer treatment in which high-energy radiation from radioactive isotopes is directed at a cancerous tumour in an effort to destroy it without destroying surrounding normal tissue

- How does **radiation treatment** help combat cancer?
- What are some of the considerations when using radiation treatment?
- What are some of the side effects of radiation treatment?

Reflect on the Big Picture

In addition to ignoring clues or checkpoints that essentially control cellular growth, cancer cells also never stop dividing. Probably the best example of this comes from cancer cells removed from Henrietta Lacks in 1951. Those cells are still in existence today. They are alive in a variety of laboratories around the world, and were even included in the Discover 17 satellite and launched into space. Though Henrietta died eight months after the cells were removed, her cancer cells have provided opportunity for research and in one way helped her memory live on.

Healthy cells have a built-in countdown timer. At best, a cell can divide approximately 50 times. After that, the cell will cause its own death, or self-destruct. Many cosmetic companies and advertisements would like you to believe that you can cheat this number. The advertisements suggest that you can keep your cells healthy and dividing as usual for longer and longer periods. Is this a reasonable claim?

Earlier in the lesson, you learned about the S phase of the cell cycle. During this phase the DNA is duplicated for the next generation of cells. This is crucial, since it is DNA that contains all of the instructions necessary for cellular function. The problem is that DNA accumulates errors over time. Errors occur in the duplication process itself or from exposure to environmental **mutagenic agents**. Over time, somatic cells' DNA gets pretty beaten up. These errors in DNA can cause serious problems or diseases like cancer. To reduce the impact of these errors, every cell contains specific instructions to self destruct after about 50 divisions. It seems the **cellular clock** exists for a good reason.

mutagenic agent: a chemical or physical agent that has the ability to mutate DNA, affecting the timing of the cell cycle; increasing the rate of mitosis

cellular clock: a property of cells that allows them to go through a set number of cell divisions and then stop, whereupon the cell line dies out; sometimes called apoptosis

Cancer cells do not have a normal cell clock so they do not apoptose.

Discuss

Now that you have gained further knowledge on the cell cycle and its regulations or limits on cell growth, do you believe that research should continue to be focused on finding a fountain of youth? Is it time to accept our limits and focus on the quality of our lives now rather than focus on the potential length of our lives? Discuss your opinion with your classmates and your instructor. Summarize the important points of the discussion both for and against this research. Post your summary for others to view and store a copy in your course folder.

Module 5: Lesson 2 Assignment

Before you begin your Lesson 2 Assignment involving research on **chemotherapy**, you may wish to do the questions on page 555 of your textbook. Discuss your responses with your teacher.

chemotherapy: the use of cytotoxic drugs that inhibit cell division, usually by preventing DNA replication or interfering with the spindle mechanism of mitosis or by interfering with the supply of blood and nutrients to the tumour; applied systemically (into the bloodstream); targets cancerous cells but may also affect rapidly dividing normal cells to some degree

Knowing that certain chemicals interfere with the process of cell division, researchers endeavoured to find drugs that would help in curing cancer. This led to a cancer treatment method called chemotherapy, or treatment by chemical drugs. Since cancer cells divide rapidly and continually, any chemical that blocks cell division or kills cells while they are dividing will have a much greater effect on cancerous cells than on normal cells. However, these drugs also destroy other fast-growing cells in the body, such as hair follicles. This explains the loss of hair by cancer patients on chemotherapy.

There are now more than two dozen different anticancer drugs that can be used to treat cancer. One drug used in chemotherapy is methotrexate, which attaches to certain enzymes involved in chromosome (DNA) replication and prevents these enzymes from doing their job. Without these enzymes, new molecules of DNA cannot be synthesized. If cell division does not take place among these drug-damaged cells, none of the newly formed cells will survive.

Methotrexate can initially be quite successful, but like other similar drugs, it loses its effectiveness over time. Studies show that the cancer cells become resistant to these anticancer drugs. Researchers believe that resistance to methotrexate occurs because the drug-treated cancer cells produce multiple copies of the specific gene that is affected by the drug. Methotrexate alters the DNA molecules in cancer cells so that some genes begin to multiply uncontrollably. One of these genes directs the synthesis of the DNA-replicating enzyme, the exact enzyme that the drug inhibits. Multiple copies of this gene cause a pronounced increase in the production of the DNA-replicating enzyme, which in turn causes a dramatic increase in the rate of DNA replication within the cancer cells. This leads to an increase in the rate of cell division. Daughter cells from these altered cells also show multiple genes and a more rapid rate of cell division. Ironically, the very drug that stops cancer cells from dividing also has the effect of making these cells more resistant. Eventually, the chemical's inhibition of cell division in cancerous cells becomes ineffective and essentially useless.

Two other drugs used in the treatment of certain cancers are vinblastine and vincristine. These two drugs were discovered in the Madagascar periwinkle plant, *Catharanthus roseus*. Vincristine is very effective in the treatment of leukemia, and vinblastine in the treatment of **Hodgkin's disease**. Vinblastine doubles the chance of surviving Hodgkin's disease. Currently the only practical source of the two drugs is from this plant. However, to produce 5.0 g of vincristine, an expensive and labourious process requiring 1000 kg of periwinkle stems is used. Chemists have successfully synthesized the substances, but this is even more expensive. New methods of culturing the plants are currently being developed to speed up the production of these drugs. The medical potential of Madagascar periwinkle is a good example of *why* conserving plant diversity is so important.

Hodgkin's disease: a blood cancer of lymph tissue

Go to the Module 5: Lesson 2 Assignment in the Module 5 Assignment Booklet. Complete the assignment.

Make sure you have completed all of the questions for the Lesson 2 Assignment. Check with your teacher about whether you should submit your assignment now or wait until all of the Module 5 assignments have been completed.

Lesson Summary

During this lesson, you explored the following focusing questions:

- What are the phases of the cell cycle?
- Do all cells have the same ability to reproduce, and does this change with age?

Approximately 50 times in the life of a cell line, healthy cells will move through interphase and M phase. In interphase, from growth and production in G1, to the synthesis of DNA in S phase, and all the way through and including the preparation of G2, the cell is constantly checking its own performance and readiness for the next step in the cycle. Finally, during M phase, the cell will go through a series of stages of division involving chromosomes. Finally, during cytokinesis, the cell will physically divide or split itself in two to form two new young cells, each of which contains one copy of the parent cell's genetic instructions.

Normal cells have a limit to how many times they can divide, and they communicate and work with the cells around them. Cancerous cells do not respect either of these criteria, and this can have terrible results. If the fountain of youth is to be found by gaining control of cellular division, it will not be by following cancer's example!

Cancer cells are called "wild cells." Their life cycle involves only division. They do not enter the interphase stage where cell functions are performed. As you saw in the videos, many of the technologies and treatments of cancer involve controlling the life cycle stages of cancerous cells.

Going Beyond

Nanotechnology is a growing field that currently has an impact on virtually all science disciplines. Use search terms such as "CNN + nanotechnology + cancer + 2005" as a starting point, and then use the library, Internet, or other resources to conduct research on nanotechnology and cancer. Does this technology show promise for winning the fight against cancer? Have any human trials been conducted or considered? What are the risks involved with this technology? Are there enough regulations in place to govern its use? Create a simple report, presentation, or discussion posting to share with your peers or your teacher.

Lesson Glossary

Consult the glossary in the textbook for other definitions that you may need to complete your work.

anchorage dependence: a property of normal cells that only allows mitosis to occur when cells are attached to a substrate or surface, not floating freely

Anchorage dependence is lost in cancer, thereby allowing for metastasis to occur.

cancer: rapid proliferation (cell division) of cells that occurs when mutations result in disruption of the normal timing of mitosis; characterized by loss of density-dependent inhibition, loss of anchorage dependence, dedifferentiation of cell function, rapid metabolism, and short cell cycle

cell cycle: the period between cell divisions; divided into the phases of interphase, mitosis, and cytokinesis; may also be divided into interphase and M phase (mitosis and cytokinesis)

cellular clock: a property of cells that allows them to go through a set number of cell divisions and then stop, whereupon the cell line dies out; sometimes called apoptosis

Cancer cells do not have a normal cell clock so they do not apoptose.

chemotherapy: the use of cytotoxic drugs that inhibit cell division, usually by preventing DNA replication or interfering with the spindle mechanism of mitosis or by interfering with the supply of blood and nutrients to the tumour; applied systemically (into the bloodstream); targets cancerous cells but may also affect rapidly dividing normal cells to some degree

cytokinesis: the phase of the cell cycle after mitosis when the cytoplasm divides into two separate daughter cells

A cleavage furrow forms in animal cells; a division plate forms in plant cells.

density-dependent inhibition: a property of normal cells that allows mitosis to occur only until cells touch each other

Density-dependent inhibition is lost in cancer cells; therefore, cells begin to form on top of one another, forming masses of cells called tumours.

eukaryotic cell: a cell with membrane-bound organelles and nucleus

G1 phase: the first part of interphase where the cell is actively growing and undergoing metabolism and protein synthesis

G2 phase: the third part of interphase where the cell continues growing, metabolizing, and carrying out protein synthesis

Hodgkin's disease: a blood cancer of lymph tissue

interphase: the longest period of the cell cycle when the cell is actively growing and metabolizing; consists of G1, S, and G2 phases; DNA is in loose, stringy chromatin form not visible under the microscope

M phase: mitosis and cytokinesis together

metastasis: the tendency of some cancer cells to break off from a primary tumour and move through the blood or lymphatic systems to other locations in the body where secondary tumours form; sometimes referred to as the "spreading" of cancer

mutagenic agent: a chemical or physical agent that has the ability to mutate DNA, affecting the timing of the cell cycle; increasing the rate of mitosis

radiation treatment: cancer treatment in which high-energy radiation from radioactive isotopes is directed at a cancerous tumour in an effort to destroy it without destroying surrounding normal tissue

replication: the copying of the cell's DNA prior to mitosis so that each daughter cell has an exact copy of the mother cell's genetic material; results in sister chromatids; occurs in the S phase of interphase

S phase: the second part of interphase where DNA replication occurs in preparation for upcoming mitosis; produces sister chromatids

sister chromatids: two pieces of DNA that are identical to each other as a result of DNA replication in S phase; lie side-by-side and are buttoned together by a centromere; together make up one chromosome

spindle apparatus: a structure composed of spindle fibres; forms during prophase in mitosis to facilitate separation and movement of chromosomes in cell division

Module 5—Cell Division: The Processes of Mitosis and Meiosis

Lesson 3—Mitosis

Get Focused

You are not the same person that you were a year ago. In fact, you are not the same person you were a few seconds ago. Your cells are constantly growing, dying, and dividing. New cells replace the old cells, leading to an eventual complete turnover of many body tissues. This continuous cell replacement maintains your body and keeps you looking like you. Yet your appearance does change over time. Why? The replicated cells that replace worn out and damaged cells should be exact copies of their predecessors, but are they?

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In this lesson you will learn more about the M phase, or mitosis phase, of the cell cycle. You will also learn to describe and explain what is occurring in the different phases of mitosis. You will learn why this type of growth is important and how new cells that result from mitosis relate to their parent cell.

In this lesson, the following focusing questions will be examined:

- How are the different phases of mitosis identified and described?
- How does mitosis maintain consistency in plants and animals?

Module 5: Lesson 3 Assignment

Your teacher-marked Module 5: Lesson 3 Assignment requires you to complete a lab on cell division for assessment.

You will receive instructions about how to complete this assignment later in the lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all of the questions and place those answers in your course folder.

Explore

Read

In previous lessons you learned how cells follow a cycle. From origin, through G1, S, and G2 of interphase, the cell grows, divides its DNA, and prepares for cell division.

Mitosis is an orderly process that carefully divides a cell's chromosomes. These chromosomes are copied precisely in S phase so that each daughter cell receives the identical genetic content. When mitosis is complete, cytokinesis divides the cell physically into two identical daughter cells, which are exact replicas of the parent cell.

Mitosis is a process, and is actually more of a continuum than a set of snapshots. However, for study purposes, mitosis is divided into four distinct phases: **prophase**, **metaphase**, **anaphase**, and **telophase**. These phases are very important. PMAT is an easy mnemonic that can be used to remember the order of the phases and is a great study and memorization tool!

prophase: the first phase of mitosis where visible chromosomes appear scattered through a cell; nuclear membrane dissolves; centrioles move to opposite poles, forming a spindle between them

metaphase: the second phase of mitosis where chromosomes line up on the equator (metaphase plate) and attach via their centromeres to a spindle fibre

Each centromere replicates so each sister chromatid has its own to allow spindle fibre to attach.

anaphase: the third phase of mitosis where spindle fibres contract, pulling sister chromatids of each chromosome apart to opposite poles

telophase: the fourth phase of mitosis where nuclear membranes form around the two groups of chromosomes; spindle apparatus dissolves; chromosomes decondense to become chromatin

centrioles: organizing bodies of the spindle

As they move apart in prophase, spindle fibres stretch out between them, forming the spindle apparatus.

Read pages 557 and 558 and consider the summary of the phases in "Figure 16.8" on page 557 of your textbook. Summarize the information about these phases for your course folder. Study both the computer graphic and the actual slides of each phase that follow, noting the **centrioles** and spindle apparatus in prophase.

Watch and Listen

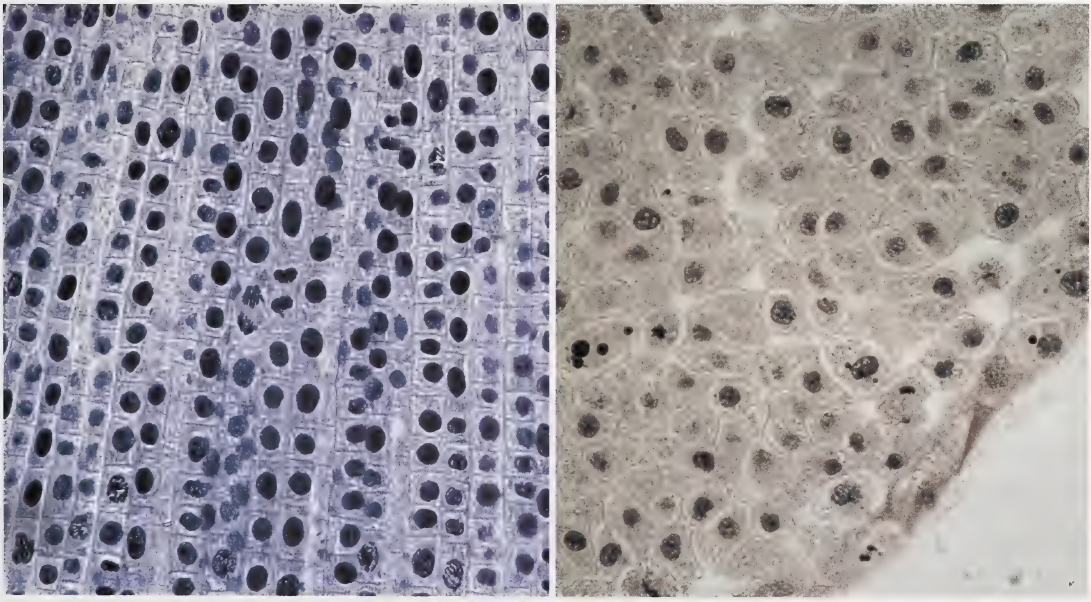
You should now have functional knowledge of each of the phases of mitosis. Review how they work together by watching the animation "Mitosis and Cytokinesis," which you can access from the multimedia DVD. Pay attention to key events and structures of each phase that will help you develop answers to the following questions:

- What happens to the nuclear membrane before, during, and after mitosis?
- What roles or actions do the spindle fibres fulfill?
- How do the chromosomes line up along the equatorial plate? **Note:** This animation uses the term **kinetochore** when referring to the centromere. Either is acceptable terminology.

kinetochore: another word for centromere; the small body holding the sister chromatids together as one chromosome; attaches to a spindle fibre at the metaphase plate

Read

Consider the two slide images below. How are they similar? How are they different?



If you have good observation skills, you should notice two clear differences between plant and animal mitosis.

First, plant cell walls are rigid and cannot go through cleavage. Instead, a new cell wall is formed between the daughter cells. This is called a cell plate.

Second, plant cells do not have centrioles. They do form a spindle apparatus to move chromosomes around, but must anchor this apparatus to the cell wall instead of to the centrioles as animal cells do.

Read "Cytokinesis" and "Mitosis and Cytokinesis in Plant Cells" on pages 558 and 559 of your textbook. A table is an excellent tool for summarizing the differences between plant cell and animal cell cytokinesis.

Module 5: Lesson 3 Assignment

Go to the Module 5: Lesson 3 Assignment in the Module 5 Assignment Booklet. Complete the lab that follows, and answer the questions in the Lesson 3 Assignment. You will receive instructions later in this lesson about how to submit the assignment.

Lab—Cell Division

You have two options for completing this lab: a lab simulation or an investigation from your textbook.

Cells follow a cycle, or a series of stages, when they divide to form more cells. The major divisions are interphase, mitosis, and cytokinesis. Interphase is characterized by growth and protein production. It is also around the mid-point of this phase that DNA is duplicated. Mitosis is the organized sequence of events that divides the cell's genetic information into two identical sets of chromosomes, while cytokinesis is the physical division of the cell. Knowing this, how many cells in any given population will be in each stage of the cycle at any time?

For this lab you may choose to complete Option A **or** Option B. Discuss with your teacher which option you have chosen before beginning the work.

Option A

To complete the lab simulation, "Cell Division Exploration," use the following directions.

Problem (Purpose)

Manipulate the total length of a cell cycle and observe how many cells in a population will be in any given stage of that cycle.

Materials

For this simulation, you will require access to the Internet and a word-processing program to record your results.

Procedure

Go to the multimedia DVD and open the "Cell Division Gizmo." When accessing this gizmo, you may be prompted for a LearnAlberta username and a password. Check with your teacher for this information.

As you read and follow the instructions, make sure you are able to answer the questions listed. Some of them will be repeated in the Lesson 3 Assignment for you to submit to your teacher.

You may choose to complete the "Assessment Questions" in the simulation and check your answers.

Option B

Complete "Investigation 16.B: Observing the Cell Cycle in Plant and Animal Cells" found on pages 559 and 560 of your textbook. Use the data you recorded in a copy of the table found on page 560 of the textbook, your calculations and answers to the "Analysis" questions, and the table you created in the "Conclusion" to complete the Lesson 3 Assignment.

Try This

TR 1. The following two interactive diagrams of mitosis can be accessed from the multimedia DVD. Label the diagrams correctly.

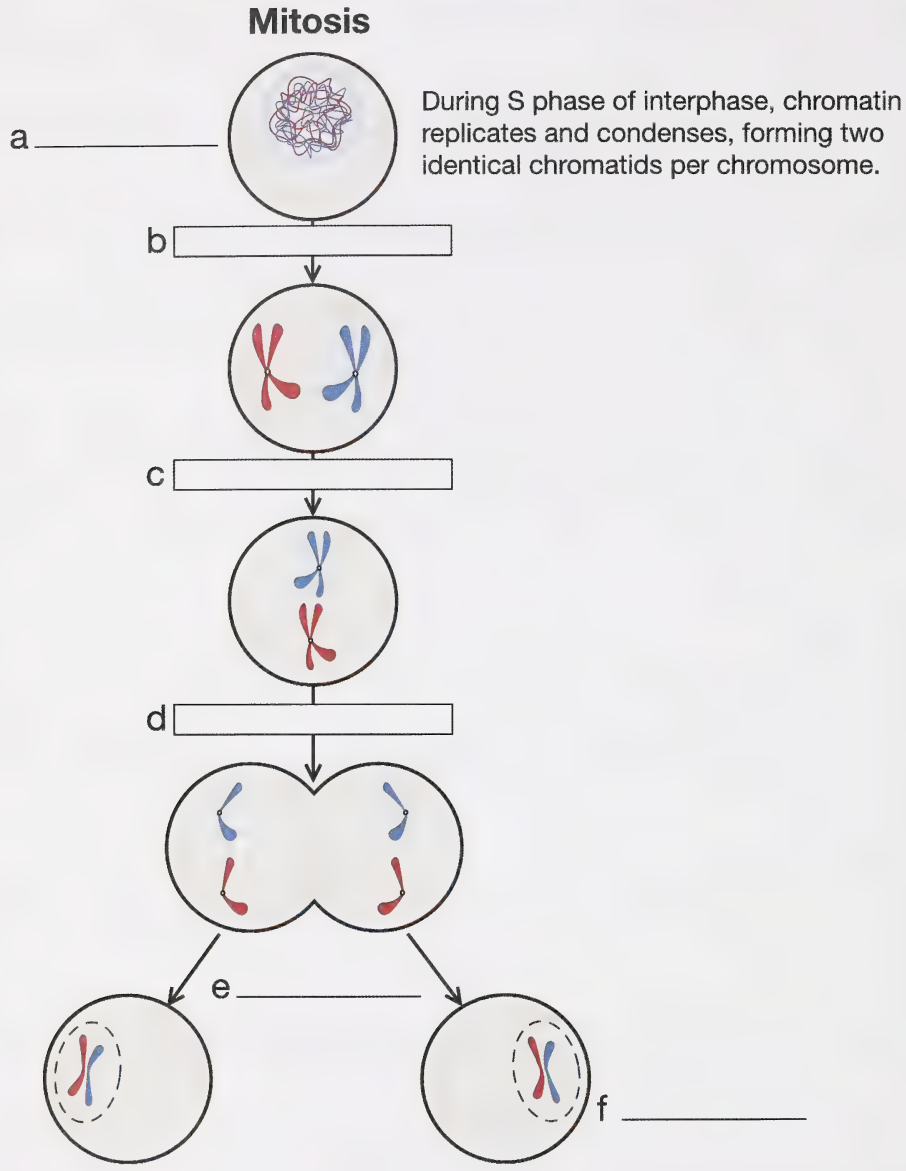
- Mitosis Overview 1
- Mitosis Overview 2

Self-Check

To apply your understanding, complete the following questions on mitosis and cellular division, and then check your answers. If you have questions or need clarification, consult with your teacher.

SC 1. Label the following terms on the flow chart below:

- mother cell in S phase of interphase
- daughter cells following cytokinesis
- anaphase
- metaphase
- prophase
- telophase



SC 2. A skin cell taken from a chimpanzee contains 48 chromosomes.

a. How many chromosomes would there be in the nerve or bone cells of this animal?

b. If a skin cell of the chimpanzee underwent cell division, how many chromosomes would there be in each daughter cell?

SC 3. What role do centrioles play in cell division of animal cells?

SC 4. Match the events described in statements a.–h. with the correct stages of mitosis (A.–E.).

Stages				
A. interphase	B. prophase	C. metaphase	D. anaphase	E. telephase
Statements				
_____ a.	Normal growth and functioning of the cell occurs here.			
_____ b.	Chromosomes replicate to produce two sets of chromosomes in preparation for cell division.			
_____ c.	Chromosomes with their duplicates still attached shorten by coiling, thus becoming visible under the microscope.			
_____ d.	Centrioles migrate to opposite sides of the cell and the nuclear membrane dissolves.			
_____ e.	Spindle fibres grow from each centriole and attach to the centromere of each chromatid pair.			
_____ f.	Chromatid pairs still joined at the centromere line up along the middle of the cell, called the metaphase plate.			
_____ g.	Chromatids are pulled apart by shortening of the spindle fibres. One complete set of chromosomes is pulled to each pole.			
_____ h.	Chromosomes uncoil, spindle fibres dissolve, and cytoplasm divides. Two daughter cells are formed.			

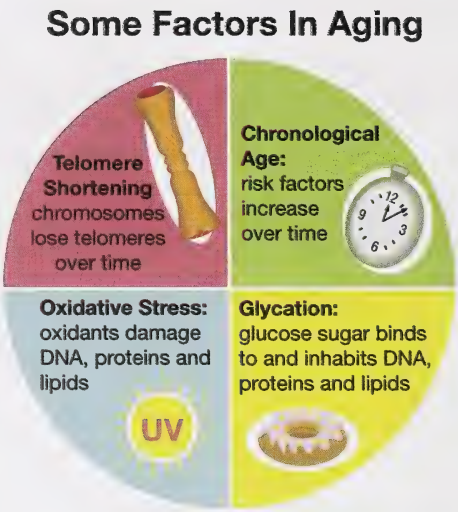
SC 5. Name the process of cytoplasmic division, and describe how it is different in plant and animal cells.

Check your work with the answers in the Appendix.

Reflect and Connect

By creating copies of DNA in S phase, and then carefully separating those identical sets of DNA into new cells during mitosis, cells ensure that the next generation has all the information it needs to continue life. Each new cell has the same number of chromosomes as its parent cell. Through this process, succeeding generations are provided a similar set of characteristics.

However, bodies do change over time. For example, human skin is not as elastic in old age as it is in youth. What could be causing this? The source of aging seems to be twofold. One factor is built into the process of copying of DNA, while the other is linked to environmental stress.



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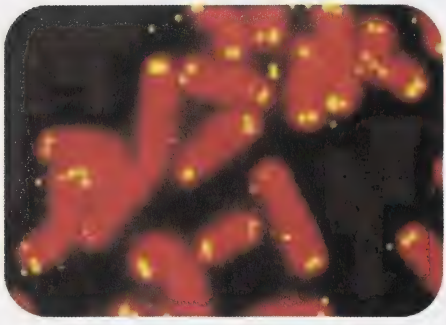

U.S. Dept of Energy, Human Genome Program

In addition to environmental stress, DNA faces challenges from within. Each time DNA is copied in S phase, it is not perfectly copied. Instead, the ends of chromosomes, known as **telomeres**, are shortened just a bit. Telomeres protect the chromosome in much the same fashion as a plastic tip protects a shoelace. When these ends are too short, the chromosomes can no longer be copied and they do not function properly; as a result, the cell and its line die. Cells can divide 50 times at best, no more.

telomere: a section on each end of a chromosome that shortens with each mitotic division

If the telomere is too short, the cell no longer divides.

The environment in which you live is harsh. There are all kinds of chemicals and radiation that can break up human DNA or cause changes known as mutations. An example of these chemicals is known as oxidants. These are highly reactive substances containing oxygen, which are always present but that increase with infection and with consumption of alcohol, cigarettes, and highly processed foods. Another concern is high levels of glucose, which can bind to DNA and cause it to stop functioning. Mutation, oxidants, and high glucose can all cause cells to die. Even if the cells escape death, the cell line may be forever reduced in function or become a cancerous growth.

Read more about cancer and the application of the principles of mitosis on pages 560 to 561 of your textbook.

Discuss

A lot of attention has recently been given to telomeres and their role in the aging process. Cancer cells seem to pay attention to them too, as most cancers turn on a gene to create telomerase, an enzyme that will prevent the shortening of telomeres. However, telomeres are not the single factor in aging. Excess sugar, alcohol, smoke, and processed foods full of chemicals seem to cause far greater damage to DNA and can shorten your lifespan. Research and its funding are limited. Should the focus be to find gene treatments to lengthen telomeres, or should focus be given to programs that encourage people to reduce behaviours that put their health and longevity at risk?

Take a position on this issue and communicate it to your classmates and your teacher in the course discussion area.

Try This

TR 2. What three functions does mitosis serve in your body?

TR 3. In which phase of mitosis does each of the following events occur?

a. migration of sister chromatids to opposite poles
b. condensation of chromatin into compact chromosomes
c. formation of a nuclear membrane
d. alignment of chromosomes along the cell equator

TR 4. Sketch the four phases of mitosis. Include labels to explain what is happening in each phase.

TR 5. What role does the spindle apparatus play in cell division?

TR 6. Briefly explain the link between cell cycle regulation and cancer.

TR 7. The scientists in a lab have isolated a substance that prevents cells from synthesizing microtubules. What impact would this substance have on cell division? Explain.

TR 8. A scientist studying a group of somatic cells notices that upon the completion of the cell cycle, half of the daughter cells have no chromosomes and the other half have 92 chromosomes. In what phase of mitosis did an error likely occur? Explain your reasoning.

Discuss your answers with your teacher and save them to your course folder for later review.

Reflect on the Big Picture

Throughout their life cycle, human bodies require continual renewal. Due to environmental stress and injury, cells die and must be replaced. Mitosis provides very quick and effective cell division. Starting with just one cell, mitotic division will quickly cover damaged or infected tissue with healthy new cells. These new cells will all function like their parent cell, will have the same number of chromosomes, and will be nearly genetically identical. All members of your family will not undergo mitotic division at the same rate or with the same effectiveness. A sister or brother just entering a growth spurt will have dramatic rates of mitosis. Grandparents or great-grandparents will have many cell lines that can no longer effectively reproduce new cells. The shorter cell cycle as cells age eventually puts a limit on the body's life cycle.

Going Beyond

Pop a pill or change your lifestyle.

In this lesson you were introduced to two factors that cause aging. One is built into cells, but the other is environmental. Environmental factors have been linked to "risky" behaviours, like overeating, consuming alcohol, or smoking. A lot of research goes into creating medications or treatments that combat the effects of these behaviours.

Using the Internet, your local library, or other community resources you might have access to, conduct your own research to find out about new treatments or medications that are being introduced to the market to combat the negative effects of certain lifestyle choices. Organize your findings into a presentation style of your choice, and share it with your classmates in the course discussion area.

Module 5: Lesson 3 Assignment

Make sure you have completed all of the questions for the Lesson 3 Assignment. Check with your teacher about whether you should submit your assignment now or wait until all of the Module 5 assignments have been completed.

Lesson Summary

During this lesson you explored the following focusing questions:

- How are the different phases of mitosis identified and described?
- How does mitosis maintain consistency in plants and animals?

Mitosis is the orderly separation of doubled chromosomes into new daughter cells. Through prophase, metaphase, anaphase, and telophase, the cell carefully ensures each new cell has a complete set of chromosomes. By undergoing this division, plant or animal tissue lines are continued faithfully until time and exposure to the environment cause a breakdown.

Lesson Glossary

Consult the glossary in the textbook for other definitions that you may need to complete your work.

anaphase: the third phase of mitosis where spindle fibres contract, pulling sister chromatids of each chromosome apart to opposite poles

centrioles: organizing bodies of the spindle

As they move apart in prophase, spindle fibres stretch out between them, forming the spindle apparatus.

kinetochore: another word for centromere; the small body holding the sister chromatids together as one chromosome; attaches to a spindle fibre at the metaphase plate

metaphase: the second phase of mitosis where chromosomes line up on the equator (metaphase plate) and attach via their centromeres to a spindle fibre

Each centromere replicates so each sister chromatid has its own to allow spindle fibre to attach.

prophase: the first phase of mitosis where visible chromosomes appear scattered through a cell; nuclear membrane dissolves; centrioles move to opposite poles, forming a spindle between them

telomere: a section on each end of a chromosome that shortens with each mitotic division

If the telomere is too short, the cell no longer divides.

telophase: the fourth phase of mitosis where nuclear membranes form around the two groups of chromosomes; spindle apparatus dissolves; chromosomes decondense to become chromatin

Module 5—Cell Division: The Processes of Mitosis and Meiosis

Lesson 4—Meiosis

Get Focused

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Legend has it that everyone has a double—someone somewhere in the world looks just like you. Genetically, this is impossible unless you have an **identical twin**.

> **identical twins:** result of one egg fertilized by one sperm; occurs when the morula splits into two masses that develop independently in the uterus; offspring are genetically identical

The reason for variation in individuals, meiosis, is the focus of this lesson. Unlike mitosis, where daughter cells are nearly identical, meiosis creates unique daughter cells called gametes by separating chromosome pairs. The average human male will create about 525 billion sperm (male gamete cells) over a lifetime, and not one will be the same genetically. In Unit B you learned that a sperm must fertilize an egg (female gamete cell) to create a new person. In this unit you will begin to understand the impossibility of there randomly being two individuals exactly alike. The creation of gamete cells is all about variation. This variation ensures the survival of a species, as you will discover later in Unit D.

This lesson may take longer than 80 minutes to complete. You should devote the time necessary to ensure your understanding of meiosis.

In this lesson you will learn to describe the stages of meiosis, and you will come to understand when meiosis is necessary, as well as how it differs from mitosis. You will learn the major sources of genetic diversity, and why this is important to a species.

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In this lesson you will examine the following focusing questions:

- How does meiosis contribute to **genetic variation**?
- What differences exist between identical and **fraternal twins**?

genetic variation: the permutations and combinations of genes and alleles possible; refers to different combinations of mother's and father's alleles in gametes; increases variation in the offspring and translates into better odds of offspring survival in changing environments

fraternal twins: two siblings born at the same time, resulting from the accidental ovulation of two eggs, which are fertilized by two sperm

Fraternal twins are as different as any two siblings.

Module 5: Lesson 4 Assignment

You will receive instructions on how to complete this assignment later in the lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all of the questions and place those answers in your course folder.

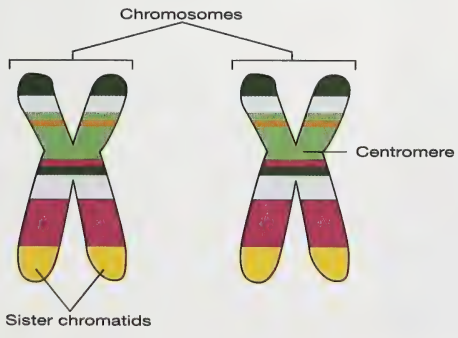
Required Materials and Equipment

You will choose the materials you want to work with to create a cell model.

Explore

Read

In Lesson 3 you discovered that mitotic division results in two identical daughter cells with the same number of chromosomes as the parent cell. Mitosis is efficient for growth and repair, but it creates very little variation in a species if used for reproduction. In Biology 20, you learned that variation drives natural selection and allows a species to survive.



Variation is the result of a species that reproduces sexually. Sexual reproduction involves meiosis and fertilization. Meiosis creates cells with half the normal chromosome number and varies the combinations of genes present on those chromosomes.

Reduction Division

In Lesson 1, you learned that humans have 46 chromosomes organized into 22 homologous pairs and one sex pair. Homologous pairs have the same type of genes, but may not have the same forms of genes as each other. For example, they may each carry the gene for blood type, but one chromosome codes for Type A and the other codes for Type B. Cells that have homologous pairs have two complete sets of genetic information. These cells are known as **diploid** or **2*n***.

diploid: the chromosome number of a somatic (body) cell; both chromosomes of each homologous pair are present; two sets of chromosomes are present, one from each parent

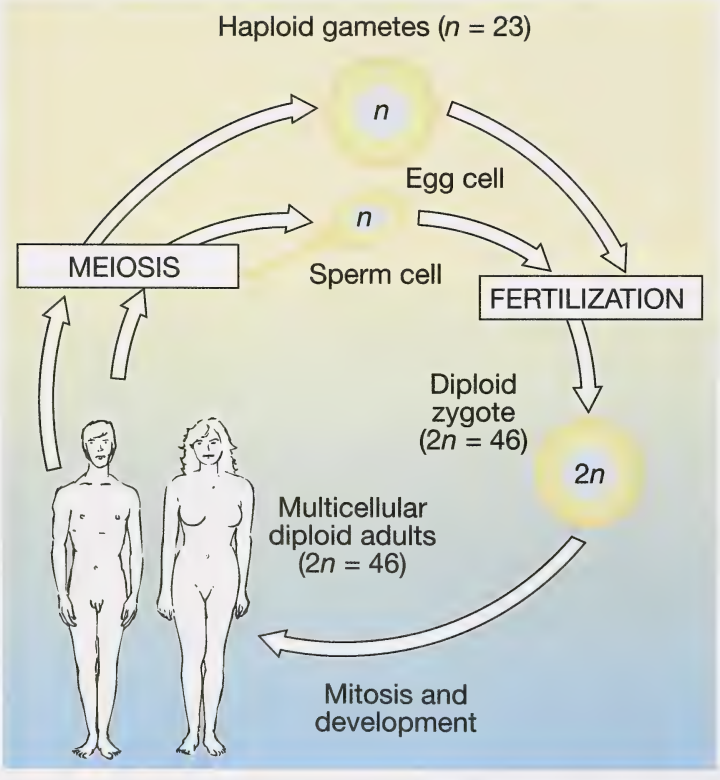
2*n*: the symbol referring to a diploid cell

haploid: chromosome number of a gamete (sex cell—egg or sperm), resulting from meiosis; only one chromosome of each homologous pair is present; one set of chromosomes present

***n*:** symbol referring to a haploid cell

ploidy: refers to the chromosome number of a cell or how many sets of chromosomes are present; haploid cells have one set, diploid two, tetraploid four, octoploid eight

The cells that result from meiosis have only one complete set of genes and are known as **haploid**, or ***n***. The number of genetic sets in a cell is referred to as its **ploidy** count. In humans, all of the body cells, called somatic cells, are diploid ($2n$). Only the gametes, sperm or eggs, are haploid (n).



To prepare for meiosis, the cell duplicates its chromosomes in S phase. Then it goes through two division cycles: **meiosis I** and **meiosis II**. The goal of meiosis I is to separate homologous pairs of chromosomes. This will reduce the number of chromosomes by half. The goal of meiosis II is to pull apart the sister chromatids. This same event was a goal in mitosis when sister chromatids were separated.

To learn about each specific stage and function in meiosis, read pages 563 to 565, up to "Sources of Genetic Recombination," in your textbook. Pay close attention to prophase I. A lot of very important work occurs in prophase I of meiosis. Here, homologous chromosomes come together and find their pair in a process called **synapsis**. Since each chromosome is made up of two sister chromatids, when homologous chromosomes come together in a pair, there are four chromatids. The temporary bundle they form is called a **tetrad**.

meiosis I: the first division of meiosis; preceded by DNA replication in interphase; results in one secondary oocyte and first polar body in females and two secondary spermatocytes in males

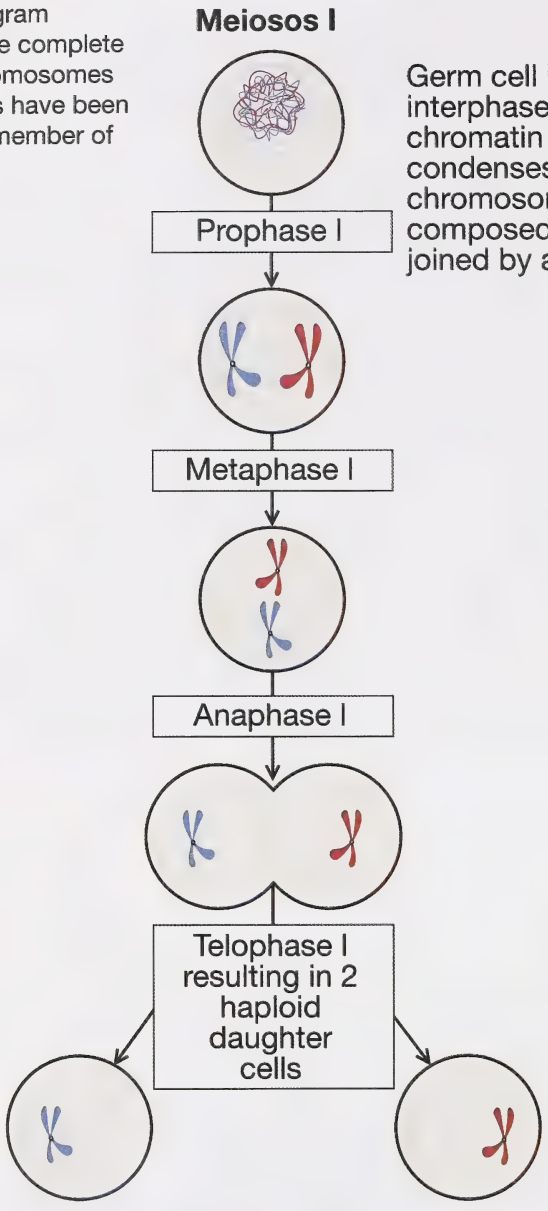
Because homologous pairs are separated from each other in anaphase, cell products are already considered haploid.

meiosis II: the second division of meiosis; no DNA replication in interphase; results in one haploid ootid and second polar body in females and four haploid spermatids in males

synapsis: the entwining of the homologous pair and attached sister chromatids in prophase I of meiosis; crossing-over between non-sister chromatids may occur

tetrad: formed in prophase of meiosis I when homologous pairs and their attached sister chromatids find each other and entwine in synapsis; may undergo crossing-over with non-sister chromatids, increasing variation in the gametes that result

Note: the following diagram illustrates a cell with one complete set of homologous chromosomes ($2n=1$). Different colours have been used to illustrate each member of the homologous pair.



When meiosis I is complete, the chromosome number has been reduced, but they are still made up of two chromatids, or doubled. Meiosis II follows the pattern of steps you studied in mitosis and separates the two chromatids into new cells.

The final result of meiosis is four haploid (n) cells that have originated from one diploid cell. In humans, that means the starting cell has 46 chromosomes, and the resulting cells, known as gametes, have 23 chromosomes.

Watch and Listen

To ensure your understanding of meiosis, watch the "Stages of Meiosis" animation, which you can access from the multimedia DVD. Note the movement of chromosomes and compare the resulting haploid gametes to the original diploid parent.

Try This

TR 1. To find an excellent animation illustrating the concepts of mitosis and meiosis, do an Internet search using terms such as "Life's Greatest Miracles" + "How Cells Divide" + "mitosis versus meiosis."

TR 2. To emphasize the different ways chromosomes move in meiosis, do another Internet search using the term "biology activities and exhibits online + cell division exercise." When you get to the Biology in Motion website, click on "cell division excercise" and complete the activity on mitosis and meiosis.

Read

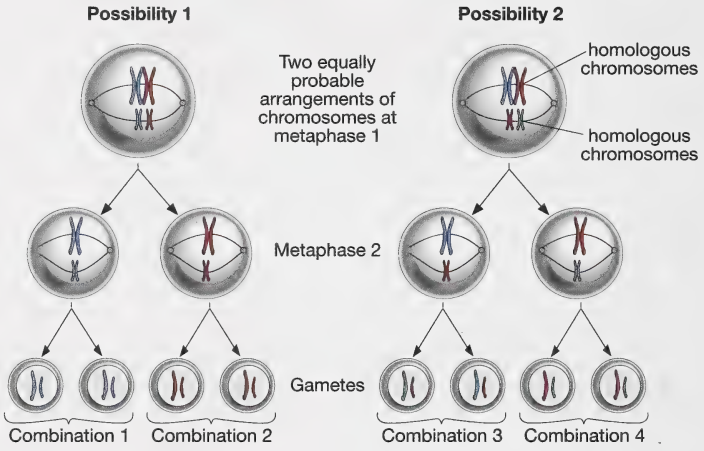
Sources of Genetic Variation—Independent Assortment

Somatic cells in the process of dividing mitotically are made up of chromosome pairs with two sets of chromosomes. Think of each chromosome as being two chromatids. Originally, one chromosome of the pair came from the male gamete (sperm), and the other chromosome of the pair came from the female gamete (egg).

independent assortment: one of Mendel's Laws of heredity (See the Lesson Glossary for a more detailed definition.)

Germ cells—in the gonads of both males and females—do not separate out the original chromosome sets; instead, new sets are formed. This is the first source of variation in meiosis and it occurs in metaphase I of meiosis. During the alignment of homologous pairs along the equator of the cell, each pair is free to arrange itself independent of others. This is known as **independent assortment**.

Consider the graphic shown here. It shows a cell with two pairs of homologous chromosomes. When the cell goes through meiosis, each alignment shown is equally likely. The end result is gametes with unique combinations. You can see that the shuffling is far greater in humans when you consider that human cells have 23 pairs, not just four! Read from "Sources of Genetic Recombination" on page 565 to the end of "Independent Assortment" on page 566 and examine "Figure 16.13" on page 566 of your text for another example.



Watch and Listen

The previous diagram uses colour and size to clarify differences in chromosomes. The homologous chromosomes are the same size and have the same kinds of genes. They are different in colour to illustrate that they contain different forms of genes. These different forms are known as **alleles**.

alleles: different versions (base sequences) of a gene or trait that will code for slightly different proteins (e.g., sickle cell hemoglobin versus normal hemoglobin)

Increased types of alleles in the gene pool increases variation and diversity and protects the species from extinction.

Since there can be many alleles on each chromosome, it is common to represent alleles with letters instead of colour.

So, an uppercase *B* and a lowercase *b* shown on a chromosome would be different alleles of the same gene (since they are the same letter). Homologous chromosomes have the same letter, but the case may vary. The significance of this practice of using uppercase and lowercase letters will be reviewed in a later lesson when you study the results of the potential **crossing over** of the parent generation.

crossing over: an occurance during meiosis I when homologous pairs and their attached sister-chromatids form tetrads, entwine in synapsis, and may be chopped by enzymes into pieces

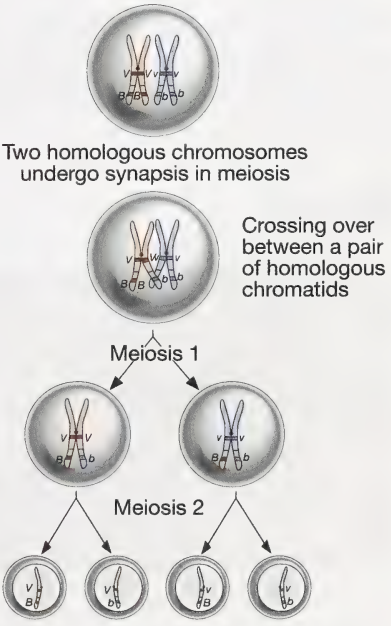
When chromosomes are reassembled, sections of the mother's homologue may be exchanged with the father's, forming chromosomes with new combinations of mother's and father's alleles. This increases variation in gametes and offspring, improving the species' chances of survival if the environment changes.

To watch an animation of independent assortment, do an Internet search using the terms "independent assortment" + "animation" + "shockwave." Then, select "animation directory" and click on "independent assortment." Use this animation to clarify the movement of homologous chromosomes and their letter assignment. You should also attempt the quiz at the end for a quick self-check.

Read

Sources of Genetic Variation—Crossing Over

Meiosis goes farther than simply shuffling the genetic deck—it actually makes new cards! Recall that during prophase I of meiosis the homologues pair up and form close groups called tetrads. Those groups are so close and so tight that sometimes small pieces from two neighbouring chromatids will break off and fuse with the other chromatid. This is known as crossing over, and it results in a chromosome with a gene combination never before seen. Read the description of crossing over on page 566 of your textbook and look at "Figure 16.14A." As you can see, without crossover, there would be no chromosomes with an uppercase *A* and a lowercase *b* possible.



Watch and Listen

Meiosis has three key components: reduction division, crossing over during synapsis, and the independent assortment of homologous chromosomes. Go to the multimedia DVD and watch "Unique Features of Meiosis," which is a good summary of those features. Consider how the resulting gametes are different from their parent cell. You may wish to make summary notes, a flow chart, or a labelled diagram to summarize this information. Store this information in your course folder.

Try This

TR 3. Although the end results of mitosis and meiosis are very unique, they do follow similar steps when it comes to sorting chromosomes. It is very important that you have a clear understanding of the differences between meiosis and mitosis. Using the search terms "Life's Greatest Miracles" + "How Cells Divide" + "mitosis versus meiosis" review the animation showing a step-by-step comparison of mitosis to meiosis when starting with the same cell. Summarize the differences between these two types of cell division in a comparative table for your course folder.

Module 5: Lesson 4 Assignment

Go to the Module 5: Lesson 4 Assignment in the Module 5 Assignment Booklet. Complete Part 1. You will receive instructions later in this lesson on when to submit your assignment to your teacher.

Self-Check

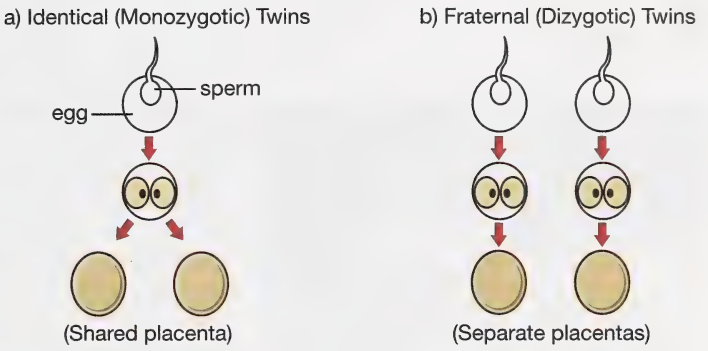
For a meiosis tutorial and quiz, do an Internet search using the search terms "biology project + cell biology + meiosis + problems." Then, select "meiosis tutorial" and choose the review notes or the "test yourself." Each problem has hints and explains why a given answer is correct. If you need further clarification or help, ask your teacher.

Read

© Stephen Mcsweeny/shutterstock

Meiosis creates unique gamete cells. This important part of the human life cycle ensures variation within the human species. Given the incredible amount of variation that can result, how is it that identical twins exist?

Identical twins start from a single egg and a single sperm. Those gametes unite to form a single diploid zygote. As the zygote begins to divide through mitosis, a disruption may occur and cause the creation of two cell masses instead of one cell mass. At this stage, cells have not begun to specialize. Any cell is capable of becoming anything in the human body.



They are known as **totipotent**. Since they have not specialized, and conditions are perfect for growth and development, each new mass grows to become a separate fetus. Since identical twins started from the same sperm and egg, they will be genetically identical.

totipotent: cells that have not specialized or differentiated (e.g., zygote, morula); all genes in the cell have the potential to be expressed (turned on)

Totipotent cells have the ability to form a complete organism.

Fraternal twins are a different story. They are the result of two different eggs being released at roughly the same time. During fertilization, each egg receives its own sperm nuclei, and the result is two separate zygotes. Each of these zygotes is genetically unique and no more related to its twin than it would be to any other brother or sister.

Reflect and Connect

Meiosis is the part of the life cycle that gives rise to variations. Through the recombination of chromosomes, random assortment during separation, and random fertilization, it is clear that no two people will look alike. That is true as long as the production of that organism is a result of meiosis and fertilization. However, in the case of identical twins, the two separate organisms are actually the result of an anomaly of mitosis, not meiosis. The fertilization event has already occurred before the single mass separates into two new cell groups. From this point on, each cellular division occurs by mitosis. Mitosis is all about keeping the genetics the same, so identical twins result.

Try This

TR 4. Complete questions 1 to 4 and 7 to 9 on page 572 in your textbook. Discuss your work with your teacher.

Discuss

Courtesy of Gary Henderson

In 1996, a sheep named Dolly made history as the first animal to be **cloned** from an existing adult sheep. In many ways, it was like making an identical twin, but the twin was much younger! This was an amazing scientific development with limitless technology applications. Some advocated cloning people to help infertile couples. Others wanted to clone all kinds of livestock to make vast herds of perfect producers. However, some problems with this procedure became evident about six years after Dolly was born. She developed arthritis and lung cancer and was eventually euthanized. Dolly's breed of sheep normally lives 12 to 15 years. The cell used for her creation was about six years old. Some speculate her chromosomes were already six years old and, therefore, she really died of old age.

clone: to create of an exact replica

A cell is a clone if it is the product of asexual reproduction (mitosis or binary fission) that produces two genetically identical cells. An organism can be a clone if it is genetically identical to another organism (e.g., animals can be cloned by taking a nucleus from one animal and inserting it into an empty egg of another, producing an offspring identical to the one that donated the nucleus). Cloning is used in agriculture and pharmaceutical industries to create uniform, consistent products.

Prepare your thoughts for a discussion with your class. Use the following questions to guide you. You will provide answers to these questions in the Lesson 4 Assignment.

D 1. Consider the benefits of cloning for preserving endangered species or advancing livestock or agriculture. Weigh this against the risks or problems you have come to understand about the technique.

D 2. Take a position on whether or not cloning should be encouraged in Canada. Defend your position and back it up with facts and information.

D 3. Describe a societal issue and an ethical issue associated with cloning.

D 4. Describe two technologies that could have been used during the cloning of Dolly.

Module 5: Lesson 4 Assignment

Once you have posted your responses to the discussion area and responded to at least two other postings, go to the Module 5: Lesson 4 Assignment in the Module 5 Assignment Booklet. Complete Part 2.

Reflect on the Big Picture

Sexual reproduction is important in the life cycle of most organisms because variation is introduced. Variation is the foundation of evolution, as well as of the understanding that the fittest will survive. However, you have seen examples of unique situations in reproduction, such as identical twins or the cloning of sheep.

Module Assessment

The options for the module assessment are described for you in the Module Summary and Assessment section, found at the end of this Student Module Booklet. Go there now to consider your options. Choose which assessment you want to complete, and begin working on your answers relating to meiosis or mitosis. How are these processes working together in your case study? If it is not possible to proceed through one kind of cell division, can you switch to the other kind of division? What would be the result if you did?

Module 5: Lesson 4 Assignment

Make sure you have completed all of the questions for the Lesson 4 Assignment. Check with your teacher about whether you should submit your assignment now or wait until all of the Module 5 assignments have been completed.

Lesson Summary

During this lesson you were to concentrate on the following focusing questions:

- How does meiosis contribute to genetic variation?
- What differences exist between fraternal and identical twins?

Meiosis is the orderly separation of homologous chromosomes into haploid gametes. Through crossover events in prophase I, and through independent assortment in metaphase I, meiosis ensures the creation of unique gametes. When fertilization later occurs, the new offspring will have a genetic combination never before seen.

Fraternal twins result from the fertilization of two individual egg cells by two individual sperm cells. Since meiosis ensures that each gamete produced by a male or female is unique, they will each be genetically different from the other. Identical twins result from the fertilization of a single egg cell by a single sperm cell. Early in development, the cell mass splits into two separate cell masses. Each mass grows by mitosis into a person. Since mitosis does not create variation, these twins are genetically the same, or identical.

Lesson Glossary

Consult the glossary in the textbook for other definitions that you may need to complete your work.

2*n*: the symbol referring to a diploid cell

alleles: different versions (base sequences) of a gene or trait that will code for slightly different proteins (e.g., sickle cell hemoglobin versus normal hemoglobin)

Increased types of alleles in the gene pool increases variation and diversity and protects the species from extinction.

clone: to create of an exact replica

A cell is a clone if it is the product of asexual reproduction (mitosis or binary fission) that produces two genetically identical cells. An organism can be a clone if it is genetically identical to another organism (e.g., animals can be cloned by taking a nucleus from one animal and inserting it into an empty egg of another, producing an offspring identical to the one that donated the nucleus). Cloning is used in agriculture and pharmaceutical industries to create uniform, consistent products.

crossing over: an occurance during meiosis I when homologous pairs and their attached sister-chromatids form tetrads, entwine in synapsis, and may be chopped by enzymes into pieces

When chromosomes are reassembled, sections of the mother's homologue may be exchanged with the father's, forming chromosomes with new combinations of mother's and father's alleles. This increases variation in gametes and offspring, improving the species' chances of survival if the environment changes.

diploid: the chromosome number of a somatic (body) cell; both chromosomes of each homologous pair are present; two sets of chromosomes are present, one from each parent

fraternal twins: two siblings born at the same time, resulting from the accidental ovulation of two eggs, which are fertilized by two sperm

Fraternal twins are as different as any two siblings.

genetic variation: the permutations and combinations of genes and alleles possible; refers to different combinations of mother's and father's alleles in gametes; increases variation in the offspring and translates into better odds of offspring survival in changing environments

haploid: chromosome number of a gamete (sex cell—egg or sperm), resulting from meiosis; only one chromosome of each homologous pair is present; one set of chromosomes present

identical twins: result of one egg fertilized by one sperm; occurs when the morula splits into two masses that develop independently in the uterus; offspring are genetically identical

independent assortment: one of Mendel's Laws of heredity

There are two uses of this term:(1) In meiosis I, tetrads line up randomly on the metaphase plate so that either the mother's or the father's sister chromatids are on one side. When all the tetrads are pulled apart in anaphase I, the chromosomes that collect at each pole are a unique combination/permutation of mother's and father's chromosomes/alleles. The orientation of one tetrad is independent of the others. (2) in reference to whether or not two genes are on the same chromosome or on different ones: If on different chromosomes, one gene (allele) is independent of the other gene in the way their tetrad lines up on the metaphase plate of meiosis I, and much gamete variation can result. If genes are linked on the same chromosome, the two genes cannot line up independently of each other—they are tied together, limiting the variety of permutations/ combinations and variation in gametes that can be formed.

meiosis I: the first division of meiosis; preceded by DNA replication in interphase; results in one secondary oocyte and first polar body in females and two secondary spermatocytes in males

Because homologous pairs are separated from each other in anaphase, cell products are already considered haploid.

meiosis II: the second division of meiosis; no DNA replication in interphase; results in one haploid ootid and second polar body in females and four haploid spermatids in males

***n*:** symbol referring to a haploid cell

ploidy: refers to the chromosome number of a cell or how many sets of chromosomes are present; haploid cells have one set, diploid two, tetraploid four, octoploid eight

synapsis: the entwining of the homologous pair and attached sister chromatids in prophase I of meiosis; crossing-over between non-sister chromatids may occur

tetrad: formed in prophase of meiosis I when homologous pairs and their attached sister chromatids find each other and entwine in synapsis; may undergo crossing-over with non-sister chromatids, increasing variation in the gametes that result

totipotent: cells that have not specialized or differentiated (e.g., zygote, morula); all genes in the cell have the potential to be expressed (turned on)

Totipotent cells have the ability to form a complete organism.

Module 5—Cell Division: The Processes of Mitosis and Meiosis

Lesson 5—Cell Cycle Disorders and Genetic Testing

Get Focused

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Chromosome replication and separation does not always go according to the patterns that you have learned. Occasionally, the process falters, and the results can be dramatic: for example, Down syndrome, Klinefelter syndrome, or Turner syndrome. In this lesson you will learn about common disorders resulting from improper cell division and consider the ethical issues involved in **prenatal genetic testing** and work with embryonic cells.

In this lesson the following focusing questions will be examined:

- How do chromosome disorders occur, and why does their occurrence increase with maternal age?
- How can embryonic cells be used, and what technologies exist to test the genetic condition of an unborn fetus?

prenatal genetic testing: sampling and testing of embryonic or fetal cells to determine chromosome number and gender

Module 5: Lesson 5 Assignment

You will complete a project on nondisjunction and questions on **stem cell** research for assessment.

You will receive further instructions on how to complete this assignment later in the lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all of the questions and place those answers in your course folder.

stem cell: an undifferentiated "generic" cell that can be coaxed into producing a number of different kinds of cells; present in embryonic blastocysts and also recently found in adults; potentially used to repair tissue and build replacement organs

Embryonic stem cell research is controversial due to the fact that the creation and termination of human blastocysts is used as a method of obtaining stem cells.

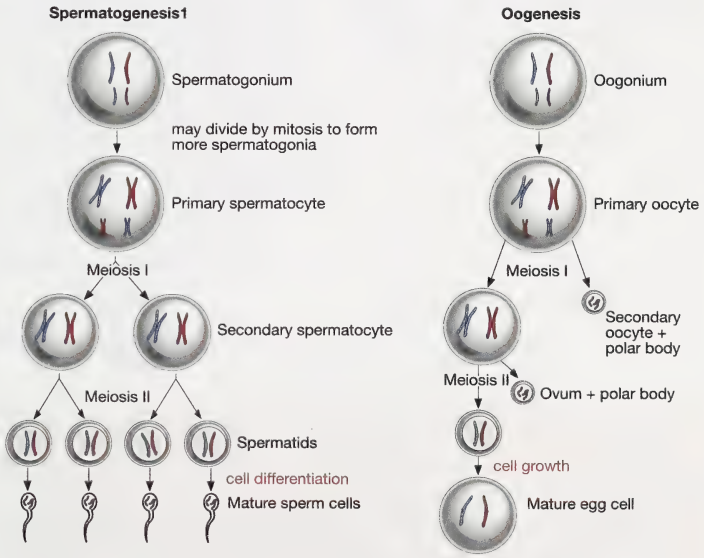
Explore

Read

To understand common chromosome disorders, you will review the normal formation of human gametes.

Spermatogenesis

In Unit B you examined how the male gamete is created in the seminiferous tubules of the testicles. Diploid germ cells known as spermatogonia can either divide by mitosis for growth, repair, and replacement, or divide by meiosis to create four haploid sperm cells (each with only 23 chromosomes). Read from page 568 to the end of "Spermatogenesis" on page 569 of your textbook. You should make summary notes, a flow chart similar to "Figure 16.16," a diagram, or any other form you choose to summarize this information for your course folder.



The process of creating sperm is known as **spermatogenesis**. Once puberty is reached, tens to hundreds of millions of sperm are produced per day.

spermatogenesis: the process of producing gametes in males; occurs in walls of seminiferous tubules of testes

Watch and Listen

Review the meiotic process of sperm formation in the "Spermatogenesis" animation, which can be accessed from the multimedia DVD. Note the difference between the **spermatogonium**, the **spermatocyte**, the **spermatids**, and the sperm.

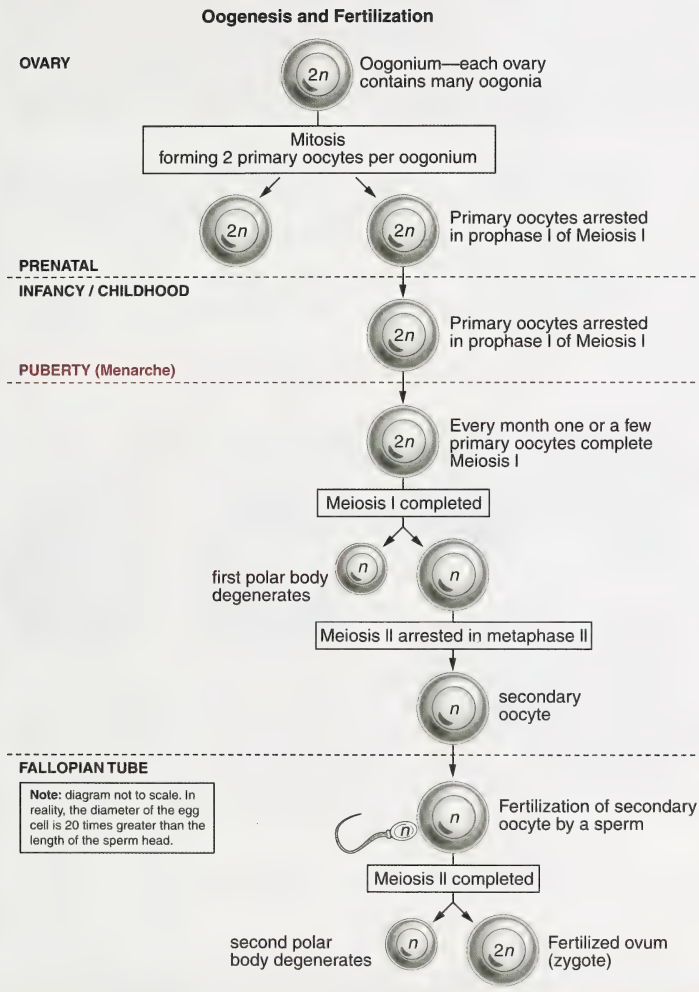
spermatogonium: the initial diploid germ cell in spermatogenesis; undergoes mitosis, forming many primary spermatocytes that each carry out meiosis

spermatocyte: cells undergoing spermatogenesis; primary spermatocyte undergoes first meiotic division, forming two secondary spermatocytes; each secondary spermatocyte undergoes second meiotic division, forming two spermatids; four spermatids formed from one primary spermatocyte

spermatids: haploid cells that result from meiosis; swim to epididymis for maturation to a spermatazoan and storage until ejaculation

Read

Oogenesis



Gamete creation in either sex occurs in the gonads and results in the reduction of the chromosomal number. However, gamete creation in the female gonads, the ovaries, differs in two important ways. First, the two meiotic divisions have unequal cytokinesis, resulting in one larger cell and three small cells that deteriorate and are reabsorbed. The small cells are called **polar bodies**. Since meiosis involves two chromosome separation events, oogenesis results in one large haploid (23 chromosomes) egg cell and two or three smaller haploid polar bodies, depending on whether or not the first polar body undergoes another mitotic division. Polar bodies are not viable gametes; therefore, they degenerate and are reabsorbed by the body.

polar body: a tiny cell that results from each division of oogenesis

Meiosis I results in large secondary oocyte and a tiny polar body that is reabsorbed. Meiosis I results in a huge ootid and a tiny second polar body that is reabsorbed. Polar bodies are "garbage cans" that extra nuclear material is dumped into to fulfill the need for one large haploid ovum.

The second key difference is timing. In males, spermatogenesis starts at puberty, and the process is very rapid. In females, oogenesis starts before birth, but freezes or stops at prophase I. Oogenesis remains at this stage until puberty. At the onset of puberty, one egg or primary **oocyte** will continue through meiosis I, and then is released into the fallopian tubes for fertilization. This is the egg cell or secondary oocyte that is matured each month as part of the menstrual cycle you studied in Unit B.

oocyte: a cell undergoing oogenesis

The primary oocyte undergoes meiosis I, producing a large secondary oocyte and the first polar body, which is reabsorbed. The secondary oocyte undergoes meiosis II, forming a large ootid and a second polar body, which is reabsorbed.

If the egg is fertilized, then it will complete meiosis II, and the final reduced nucleus will fuse with the sperm nucleus to start a new life. Read "Oogenesis" on pages 569 and 570 of your textbook. You should summarize this information in a chart, a flow chart similar to "Figure 16.16" on page 569, a labelled diagram, or into summary notes. Store your work in your course folder.

Watch and Listen

The video "Meiosis and Gamete Formation: Creating New Genetic Combinations" is an excellent review of the concepts of this module; however, concentrate on the sections "Spermatogenesis and Oogenesis" and "Gametogenesis." Notice how both result in the reduced chromosome number needed for fertilization, yet the timing and process of oogenesis is more complex and is characterized by long periods of rest or waiting.

Read

Your understanding of meiosis and gamete creation will help you understand how errors could occur in the process. Sometimes homologous chromosomes or sister chromatids fail to separate when forming haploid gametes. This is known as nondisjunction. Nondisjunction leads to gametes with either too many or two few chromosomes. Read pages 567 to 568 and examine "Figure 16.15" in your textbook. It compares nondisjunction in meiosis I to nondisjunction in meiosis II. Which one leads to more gametes with an abnormal number of chromosomes?

Try This

Recall from Lesson 1 that chromosome counts are done by creating a karyotype of cells undergoing mitosis. From this picture of cell chromosomes, you can determine how many of each type of chromosome there are and the gender of the person being tested. Some common disorders that result from nondisjunction are Down syndrome (**trisomy** 21) or Edward syndrome (trisomy 18). *Trisomy* means "three." In each of these examples, there is an extra chromosome present. Syndromes are conditions with specific characteristics that can vary widely in severity.

trisomy: offspring that have three of one kind of chromosome rather than two; occurs when an $n + 1$ gamete fuses with a normal n gamete, producing a $2n + 1$ zygote; in humans an offspring that has a diploid number of 47 rather than 46

TR 1. For practice analyzing karyotypes and diagnosing the syndrome present, complete "Lab 16.A: Modelling a Karyotype" on page 554 of your textbook. Ask your teacher for a sample karyotype. After you have completed the "Analysis" questions and "Conclusion," compare your results with a fellow student or discuss your work with your teacher.

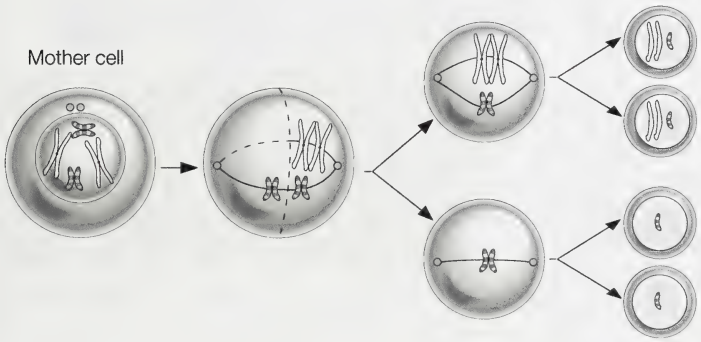
Module 5: Lesson 5 Assignment

Go to the Module 5: Lesson 5 Assignment in the Module 5 Assignment Booklet. Complete Part 1. You will receive instructions later in this lesson on when to submit your assignment to your teacher.

Self-Check

To ensure your understanding, complete the following questions on nondisjunction and abnormal meiosis and then check your answers. Ask your teacher for clarification of any concepts.

Carefully study this illustration and then answer the questions that follow.



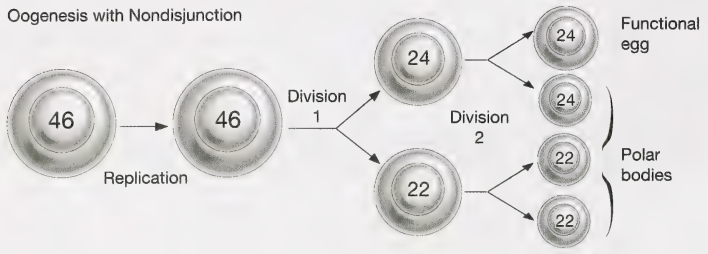
SC 1.

a. What has happened that is not normal? What is this process called?

b. Sketch a normal gamete that should arise from the mother cell.

SC 2. Name three genetic disorders that are the result of nondisjunction.

Use the flow chart showing the results of nondisjunction in meiosis I to answer question 3.



SC 3.

a. In which division has nondisjunction occurred?

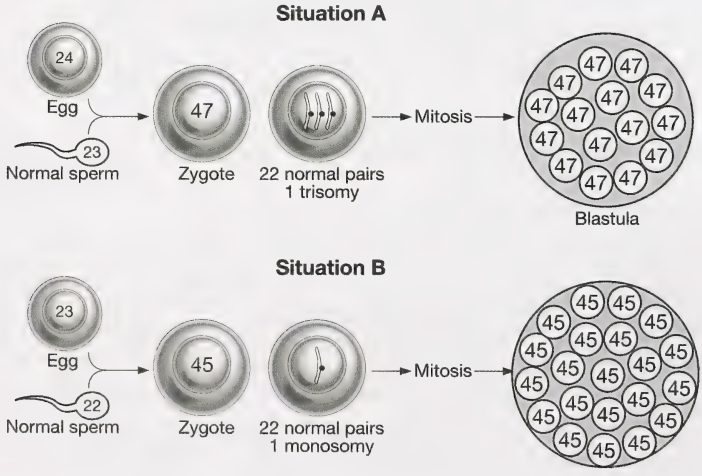
b. Why is the egg cell shown abnormal?

c. If the cell with twenty-two chromosomes were to give rise to the egg, would the egg be abnormal? Explain.

SC 4. Zygotes having an abnormal number of chromosomes are usually described by the terms **monosomy** or *trisomy*. What do these terms mean?

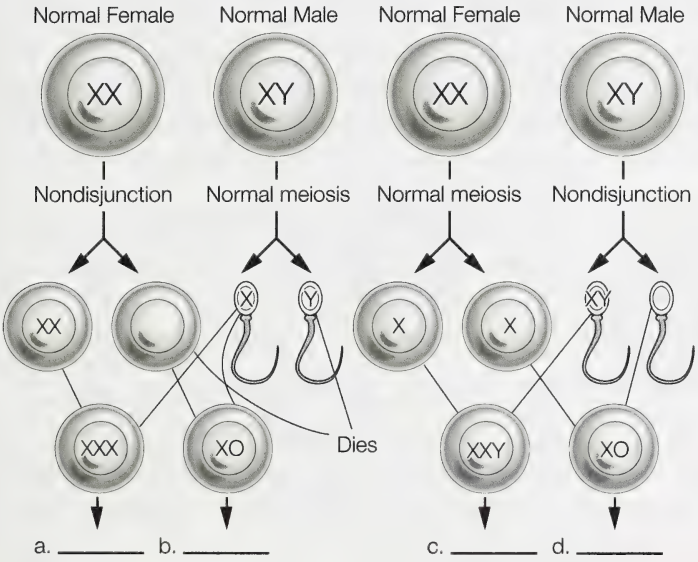
monosomy: offspring that only have one of a particular chromosome rather than two; occurs when a normal n gamete fuses with an $n - 1$ gamete, producing a $2n - 1$ zygote; in humans, an offspring that has a diploid number of 45 rather than 46

Assume the eggs that could be produced from the division shown in question 3 are fertilized as illustrated.



SC 5. Label each illustrated situation as either trisomy or monosomy.

SC 6. Identify the syndrome produced by each of the abnormal sex chromosome combinations shown in the chart.



SC 7. Some individuals may have the combination of sex chromosomes XXXY. What is the sex of this person? Explain why.

Check your work with the answers in the Appendix.

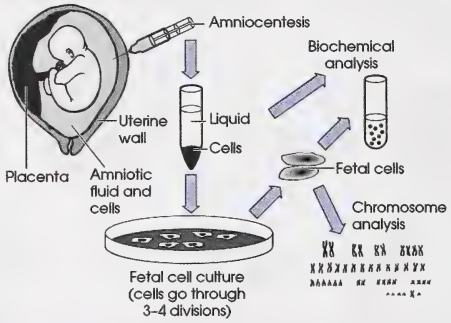
Read

There is a dramatic increase in the incidences of nondisjunction in female gametes as a woman ages. For example, the chances of having a Down syndrome child at age 25 is 1:1500, by age 30 the risk is 1:910, and by the age of 45 it is 1:30. A specific cause for this is unknown.

As a woman ages, the oocytes have been suspended in prophase I for many years. The chances have increased that the apparatus to complete meiosis properly has deteriorated. New research also indicates that a woman's womb can becomes less selective for genetically compromised embryos, making it more likely to carry an embryo with a genetic disorder to term.

Genetic Testing

Recall from your studies in Unit B the various technologies used to test a fetus for genetic problems. Three common procedures are **amniocentesis**, **cordiocentesis**, and **chorionic villi sampling**. Each differs in terms of when it can be done, which material it tests, and how quickly the answers come back. Each test is the same in terms of what is being looked for: an abnormal number of chromosomes.



amniocentesis: a needle sampling of fetal amniotic fluid to gather embryonic cells for karyotyping; determines chromosome number and gender, not presence of specific genes/alleles on chromosomes

cordiocentesis: a sampling of umbilical cord blood of a fetus for karyotyping

chorionic villus sampling (CVS): a sampling of chorionic villi through the vagina, used to obtain embryonic cells for karyotyping

Try This

TR 2. Research the following genetic testing technologies and complete a table like the following. Share your work with your fellow students in the discussion area.

Name	Description of Procedure	Advantages	Risks
Amniocentesis			
Chorionic Villi Sampling			
Cordiocentesis			

Ethical Concerns

Science is very good at seeking knowledge. However, it is not the role of science or even scientists to decide what should be done with that knowledge. Instead, this role falls on the shoulders of society. What are some ethical concerns that can arise from prenatal genetic testing? What is the tension or debate that focuses on prenatal testing? Use the discussion board to share ideas with your fellow students or discuss your ideas with your teacher.

Some groups within society may object to prenatal tests because of the possible risks to the fetus. Prenatal testing can jeopardize the pregnancy, for example, by resulting in a miscarriage or by introducing infection. Furthermore, based on the results of the testing, parents may choose to terminate the pregnancy.

Stem cell research is another controversial issue. Some people and groups may have ethical concerns because of the certain death it causes to the **blastocyst** from which these cells may be taken.

blastocyst: the embryonic stage about one week after conception; a hollow ball of cells consisting of outer trophoblast that becomes the chorion and inner cell mass that becomes the embryo; implants in the wall of the endometrium

Module 5: Lesson 5 Assignment

Go to the Module 5: Lesson 5 Assignment in the Module 5 Assignment Booklet. Based on what you have read, the videos you have watched, and any research that you have done, complete Part 2. You will receive instructions later in this lesson on when to submit your assignment to your teacher.

Watch and Listen

There is controversy about stem cell research. For information on Canada's guidelines for research, search the Internet using the terms "cbc + archives + Canada's guidelines + stem cell research" and watch the news documentary.

Reflect and Connect

Cell division and chromosome separation does not always follow the normal pattern. Nondisjunction events can lead to too many or too few chromosomes in gamete cells. After the process of fertilization involving a gamete with trisomy or monosomy, the resulting zygote will have too many or too few chromosomes, and each daughter cell from that zygote will also carry that error since mitosis will faithfully repeat the chromosome count in all of the body's somatic cells. This can lead to individuals with serious genetic conditions. Currently, science allows tests to be conducted to analyze the chromosome count of an unborn fetus, but there are no genetic treatments to reverse the problem of nondisjunction.

The knowledge of how cells divide both mitotically and meiotically, and of what can go wrong in the process, has led scientists into many fields of research and technology. For example, stem cell research involves the study of cells that have not yet differentiated or specialized in cell division. Based on the understanding of cell division, scientists are developing ways to apply stem cells in the treatment of diseases where cells no longer perform their normal function.

Discuss

Stem cell research holds much promise for finding new treatments to many serious diseases. By starting with young, undifferentiated cells, scientists may be able to generate any number of missing or malfunctioning cells in adults. However, the collection of these cells destroys the blastocyst from which they are taken. From your reading of the text on page 527, and from your review of the video on Canada's guidelines for stem cell research, take a position on whether or not Canada's guidelines give enough freedom to scientists while still respecting ethical concerns. Discuss your position with your classmates.

Reflect on the Big Picture

Proper chromosome separation is the foundation of an organism's life cycle. If the correct number and assortment of chromosomes are not present in a gamete when it is fertilized, the resulting error will be repeated throughout the entire organism when the fetus grows and develops by way of mitosis.

Unspecialized cells found in a blastocyst have not yet entered a defined cell line or cycle. As a result, they can be used to replace any damaged or ending cell lines in full grown adults. This kind of research can extend life and increase the quality of life for many people, but it must be ethically guided by careful debate on the societal level. Did you learn anything new or do you have a different perspective now that you have completed the lesson assignments and participated in the discussions? Develop a reflective paragraph that summarizes your perspective on stem cell research and submit it for feedback.

Module 5: Lesson 5 Assignment

Make sure you have completed all of the questions for the Lesson 5 Assignment. Check with your teacher about whether you should submit your assignment now or wait until all of the Module 5 assignments have been completed.

Lesson Summary

This lesson focused on the following questions:

- How do chromosome disorders occur, and why does their occurrence increase with maternal age?
- How can embryonic cells be used, and what technologies exist to test the genetic condition of an unborn fetus?

Chromosomes may not separate properly in meiosis I or meiosis II. This is known as nondisjunction. When this occurs in a gamete that is later fertilized and becomes a new individual, the result is a person with a serious condition, such as Klinefelter syndrome.

Tests like amniocentesis, cordiocentesis, and chorionic villi sampling can diagnose the presence of abnormal chromosome numbers in an unborn fetus. However, no treatments can be done to change chromosome numbers since the error is found in every cell of that new life.

Early embryonic cells are totipotent. As a result, they can become any type of cell present in the human body. It is this characteristic that causes them to be of particular interest to scientists who are trying to find cures for diseases caused by adult cells shutting down or stopping regular function. Society will need to decide upon the guidelines which will govern how scientists are allowed to use these amazing cells.

Lesson Glossary

Consult the glossary in the textbook for other definitions that you may need to complete your work.

amniocentesis: a needle sampling of fetal amniotic fluid to gather embryonic cells for karyotyping; determines chromosome number and gender, not presence of specific genes/alleles on chromosomes

blastocyst: the embryonic stage about one week after conception; a hollow ball of cells consisting of outer trophoblast that becomes the chorion and inner cell mass that becomes the embryo; implants in the wall of the endometrium

chorionic villus sampling (CVS): a sampling of chorionic villi through the vagina, used to obtain embryonic cells for karyotyping

cordiocentesis: a sampling of umbilical cord blood of fetus for karyotyping

monosomy: offspring that only have one of a particular chromosome rather than two; occurs when a normal n gamete fuses with an $n - 1$ gamete, producing a $2n - 1$ zygote; in humans, an offspring that has a diploid number of 45 rather than 46

nondisjunction: non-separation of chromosomes during meiosis; one pair gets dragged to one pole, and no representative of that pair is pulled to the other pole; if occurs in meiosis I, gametes will be two $n + 1$ gametes and two $n - 1$ gametes; if occurs in meiosis II, gametes will be $n + 1$, $n - 1$, n, and n, results in offspring that have a trisomy or monosomy for that chromosome

oocyte: a cell undergoing oogenesis

The primary oocyte undergoes meiosis I, producing a large secondary oocyte and the first polar body, which is reabsorbed. The secondary oocyte undergoes meiosis II, forming a large ootid and a second polar body, which is reabsorbed.

polar body: a tiny cell that results from each division of oogenesis

Meiosis I results in large secondary oocyte and a tiny polar body that is reabsorbed. Meiosis I results in a huge ootid and a tiny second polar body that is reabsorbed. Polar bodies are "garbage cans" that extra nuclear material is dumped into to fulfill the need for one large haploid ovum.

prenatal genetic testing: sampling and testing of embryonic or fetal cells to determine chromosome number and gender

spermatids: haploid cells that result from meiosis; swim to epididymis for maturation to a spermatazoan and storage until ejaculation

spermatocyte: cells undergoing spermatogenesis; primary spermatocyte undergoes first meiotic division, forming two secondary spermatocytes; each secondary spermatocyte undergoes second meiotic division, forming two spermatids; four spermatids formed from one primary spermatocyte

spermatogenesis: the process of producing gametes in males; occurs in walls of seminiferous tubules of testes

spermatogonium: initial diploid germ cell in spermatogenesis; undergoes mitosis, forming many primary spermatocytes that each carry out meiosis

stem cell: an undifferentiated "generic" cell that can be coaxed into producing a number of different kinds of cells; present in embryonic blastocysts and also recently found in adults; potentially used to repair tissue and build replacement organs

Embryonic stem cell research is controversial due to the fact that the creation and termination of human blastocysts is used as a method of obtaining stem cells.

trisomy: offspring that have three of one kind of chromosome rather than two; occurs when an $n + 1$ gamete fuses with a normal n gamete, producing a $2n + 1$ zygote; in humans an offspring that has a diploid number of 47 rather than 46

Module 5—Cell Division: The Processes of Mitosis and Meiosis

Lesson 6—Variation in Reproductive Strategies

Get Focused

For many life forms, existing as a gamete is a major part of their **life cycle**. For example, moss gametes grow and divide to become free-living organisms before they create a single cell that will fertilize another to become a new generation of moss. The drive to reproduce and survive has led to some very interesting strategies.

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In this lesson you will learn about the diversity in reproductive strategies for a range of organisms. You will gain an appreciation for the variety of ways species balance their life cycles.

In this lesson the following focusing questions will be examined:

- What are the advantages or disadvantages of different reproductive strategies?
- Why do some organisms vary their reproductive strategies?

life cycle: the stages an organism goes through to grow, reproduce, and die

Module 5: Lesson 6 Assignment

You will complete "Thought Lab 16.2" for assessment.

You will receive further instructions on how to complete this assignment later in the lesson.

You must decide what to do with the questions that are not marked by the teacher.

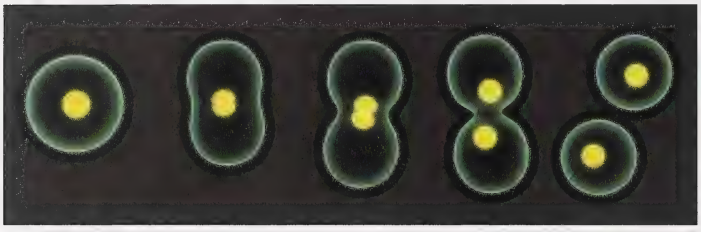
Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all of the questions and place those answers in your course folder.

Explore

Read

Lesson 1 presented the two basic methods of cell reproduction: mitosis, which creates two new daughter cells from a parent cell quickly but with little variation, and meiosis, which creates daughter cells with a reduced number of chromosomes that must fertilize or be fertilized by other cells to create varied offspring. If mitotic division leads to a new organism, it is generally referred to as asexual reproduction. If there is meiosis followed by fertilization, this leads to new offspring, and it is known as sexual reproduction.

Asexual Reproduction



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Sometimes reproduction can be very simple. Consider bacteria. They do not have chromosomes, and they hold their entire DNA in a single loop. When they divide, they duplicate their DNA loop, attach the ends of each loop to their cell wall, and grow a new wall between the loops. This process is called **binary fission** and can be completed in as little as 20 minutes. Binary fission can produce large populations of bacteria, or **prokaryotes**, quickly. As a result, each organism is identical, and the whole population could be susceptible to a toxin or a change in the environment. This toxin or environmental change could lead to the extinction of the population because no individual would have the genetic variation for resistance.

binary fission: asexual cell division in prokaryotes; replication of the circular chromosome and division of the DNA and cytoplasm without the use of a spindle; offspring are clones; rate is very rapid

prokaryotes: single-celled organisms without a nuclear membrane, such as bacteria; have one circular chromosome; divide asexually by binary fission and "sexually" by conjugation

budding: a type of asexual reproduction

In yeast, unequal cytokinesis in mitosis forms a large cell and a tiny cell that buds off; in Hydra, a small multicell mini-polyp breaks off and forms an adult.

Another quick method common to small aquatic organisms is **budding**. In budding, the parent organism begins growing a new organism from its body through mitosis. The new organism, or the "bud," then separates and becomes a new individual. In a similar way, many plants grow long horizontal stems that reach new areas and then grow new full plants, or "runners," on the ends of those stems. An excellent example is strawberry plants.

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An artificial way to reproduce much like budding is to take a cutting of a plant and encourage it to root. This kind of reproduction is called **fragmentation**. In this way, you are actually making a clone of the parent plant since the new cells will grow through mitosis. To review these and other asexual methods of reproduction, read from page 573 up to the heading "Alternation of Generations" on page 575 of your textbook.

While asexual reproduction is rare in animals, some unique cases are worth mentioning. You may be familiar with sea stars and their ability to reproduce through fragmentation. Flat worms can do it too. Even stranger, if a flat worm is cut only partway down the middle, it will regrow each half of the head that is missing and end up sharing a tail!

fragmentation: an asexual form of reproduction in animals similar to cutting in plants (e.g., a flatworm with its tail cut off can regenerate the lost section)

Other animals can produce unfertilized eggs that will grow into whole organisms. This is called **parthenogenesis**. A queen bee does this to create more sterile male drones. Female Komodo dragons can produce offspring this way when there are no males present! If there are male Komodo dragons present, reproduction is sexual.

parthenogenesis: a rare type of asexual reproduction; an unfertilized haploid egg divides by mitosis, producing a complete multicellular organism in which all cells are haploid; seen in amphibians, reptiles, and birds

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Try This

One of the advantages of asexual reproduction is the speed at which more offspring are created. To study the difference in numbers of offspring produced in sexual versus asexual reproduction, do an Internet search using the search terms "generation calculator" and "Stanford." When you load the calculator, start with a simulation of ten generations and only two offspring per generation.

TR 1. Why is there such a big difference between asexual and sexual reproduction?

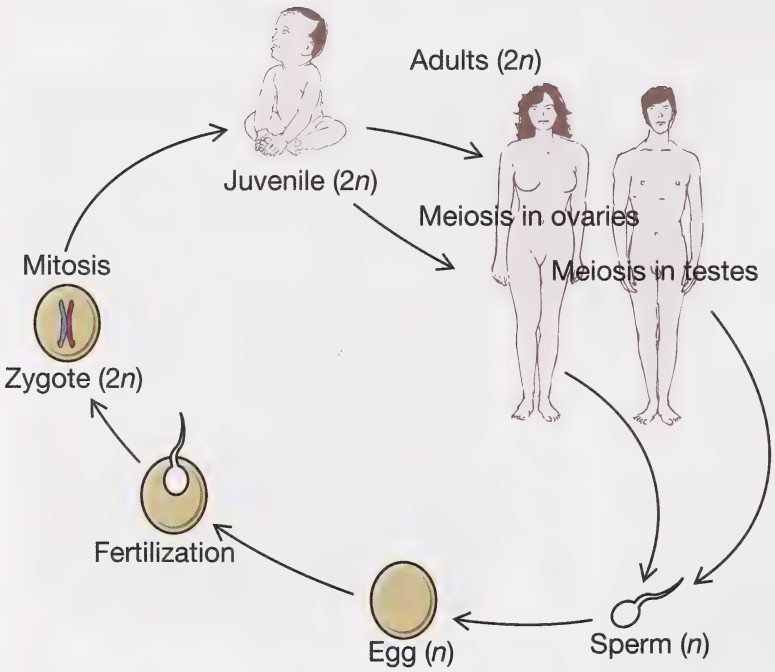
TR 2. What happens if you increase the number of offspring per generation?

TR 3. Is there a point where sexual reproduction approaches the high numbers attained by asexual reproduction?

Sexual Reproduction and Alternation of Generations

With sexual reproduction, there are always two important processes: meiosis and fertilization. These processes act as gatekeepers between life as a diploid organism and life as a haploid organism. Recall that diploid cells have two sets of chromosomes present, while haploid cells only have one. Haploid cells do not contain homologous chromosomes.

Animals do alternate between diploid and haploid. However, their life cycle is nearly completely dominated by the diploid generation. The haploid side does not grow and produce large cell masses through mitosis.



Plants alternate between haploid and diploid generations with growth on both sides. This variance between generations is known as **alternation of generations**. The diploid generation is referred to as the **sporophyte** generation, as it produces haploid **spores** to start the next generation. Each haploid spore grows through mitosis into a multicellular structure referred to as the **gametophyte**. It is the gametophyte that actually produces male and female gamete cells that will fertilize to form a new sporophyte generation. Read from "Alternation of Generations" on page 575 to the end of page 577 of your textbook for more information.

alternation of generations: a plant life cycle where two distinct multicellular forms of a sporophyte and a gametophyte occur in one generation

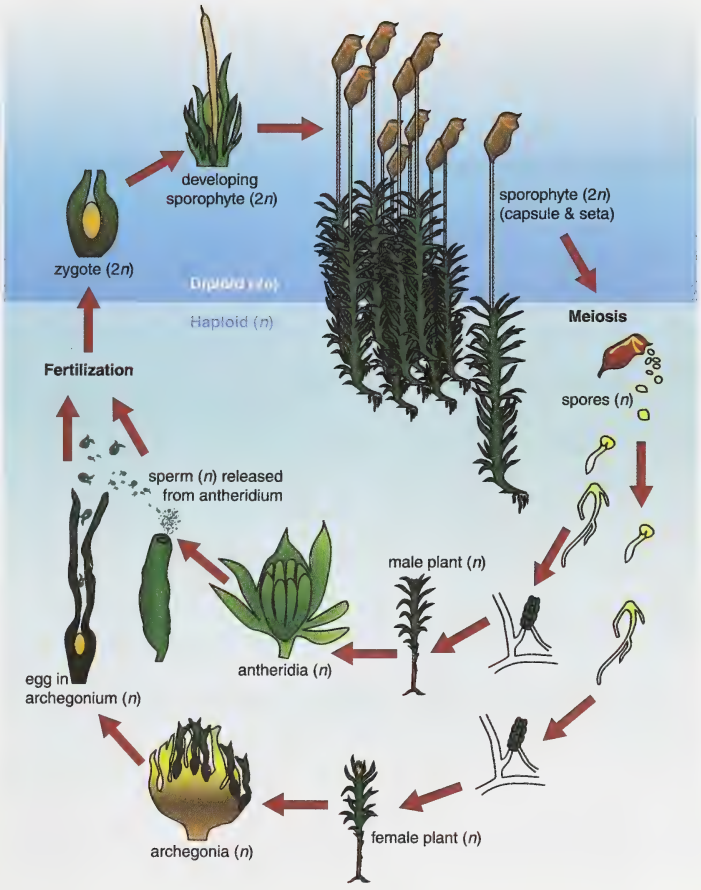
A diploid zygote undergoes mitosis to form a diploid sporophyte, which undergoes meiosis to form haploid unicell spores, each of which undergo mitosis to form a multicellular haploid gametophyte, which undergoes mitosis to form unicellular gametes, which fuse with other gametes to produce a diploid zygote. Animals do not display alternation of generations.

sporophyte: the diploid multicellular stage in plants that show alternation of generations; produces haploid spores by meiosis

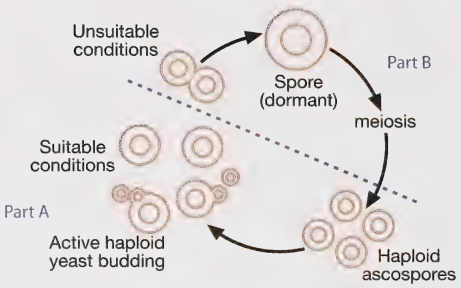
spore: a haploid cell produced by meiosis in the sporophyte; each is capable of dividing to form a multicellular gametophyte consisting of haploid cells

gametophyte: a multicellular stage in alternation of generations that consists of haploid cells that split off to produce haploid gametes

Ferns are an example of alternation of generations. Consider the graphic here or on page 576 in your textbook. Can you tell which generation is haploid and which is diploid? Remember, haploid means only one set of chromosomes (n), so no homologues are present, while diploid means to have two sets or ($2n$). Note the role of mitosis, meiosis, and fertilization in alternation of generations. The process that changes an organism from haploid to diploid is fertilization. The process that reduces the organism back to haploid is meiosis.



Some life forms will reproduce either sexually or asexually. Bacteria are a good example of this versatility in reproduction. They may reproduce asexually by binary fission, or grow extensions into neighbouring bacteria and exchange genetic information. This is called **conjugation**, and it results in a new, genetically varied daughter cell. Yeast can also reproduce many times asexually; and if conditions are harsh, they will fuse with another yeast cell and form a spore. This spore can resist drying out and may lay dormant for a long time. When conditions are favourable, the spore will undergo meiosis to form haploid yeast cells that will likely colonize through budding (mitosis).



conjugation: a type of sexual reproduction that occurs when two cells form a cytoplasm bridge through which they exchange genetic material, producing variation; occurs only in unfavourable environments

What are the potential advantages and disadvantages of each type of reproduction? Read pages 578 to 580 of your textbook. Create a summary table or graphic organizer for each type of reproduction and save it in your course folder for review.

Watch and Listen

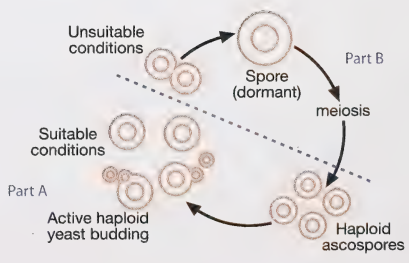
To review mitosis, meiosis, and how they are part of various reproductive strategies, watch the video "Asexual Reproduction and Alternation of Generations: Successful Game Plans for Survival." Compare their lists of advantages and disadvantages with the lists you have created.

Module 5: Lesson 6 Assignment

You will complete "Thought Lab 16.2: Comparing Reproductive Strategies" on page 579 of your textbook for assessment. Go to the Module 5: Lesson 6 Assignment in the Module 5 Assignment Booklet. Complete the assignment. You will receive instructions later in this lesson on when to submit your assignment to your teacher.

Self-Check

Carefully study this illustration, and then answer the questions that follow.



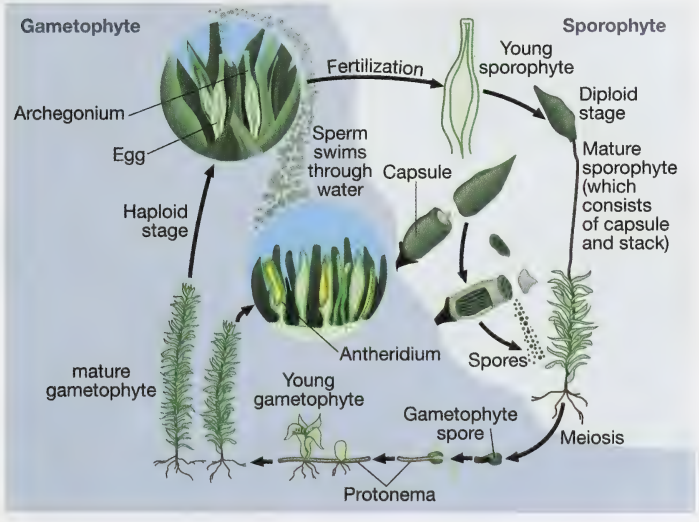
SC 1. What kind of cell division is involved in the budding process? Explain.

SC 2. When a yeast cell undergoes meiosis, how many ascospores are produced? Is this consistent with what you would expect for this kind of division? Explain.

SC3. The life cycle of yeast can be divided into two phases. Which one is the sexual phase and which one is the asexual phase?

SC 4. What seems to trigger sexual reproduction in yeast cells?

Carefully study this illustration, and then answer the questions that follow.



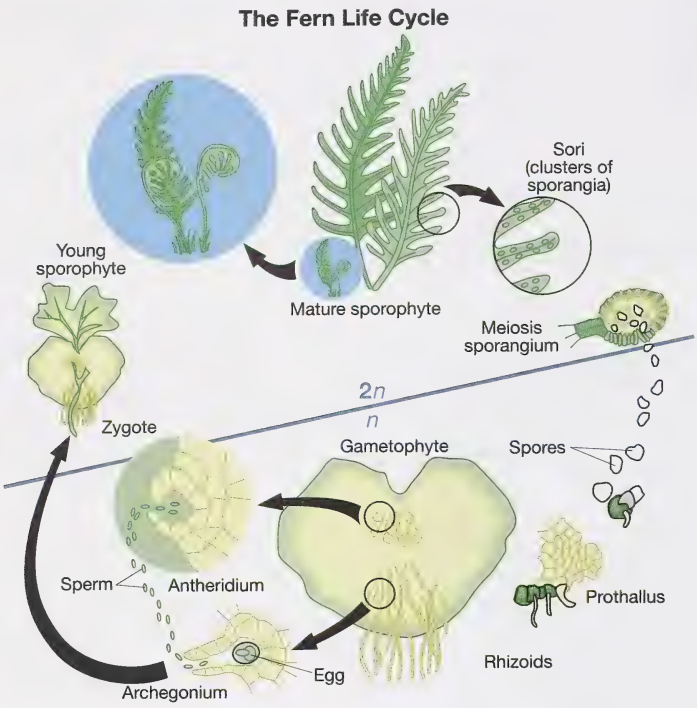
SC 5. What kind of cell division is involved in the production of gametes in mosses? Explain why.

SC 6. Identify the units produced by the reproductive process in mosses and the structure where meiotic divisions occur.

SC 7. Why do mosses need moist conditions to reproduce?

SC 8. With regards to dispersal, what is the advantage of producing spores?

SC 9. Is the dominant stage in a moss' life cycle haploid or diploid?



SC 10. Use the fern life cycle to answer the following questions:

a. Is the dominant stage of a fern a gametophyte or a sporophyte?

b. Are the cells of a fern diploid or haploid?

c. Do ferns produce gametes or spores for reproduction?

d. Are spores produced by meiosis or mitosis?

e. Are spores haploid or diploid?

f. Is a small prothallus a gametophyte or a sporophyte?

g. Does the heart-shaped prothallus produce gametes or spores?

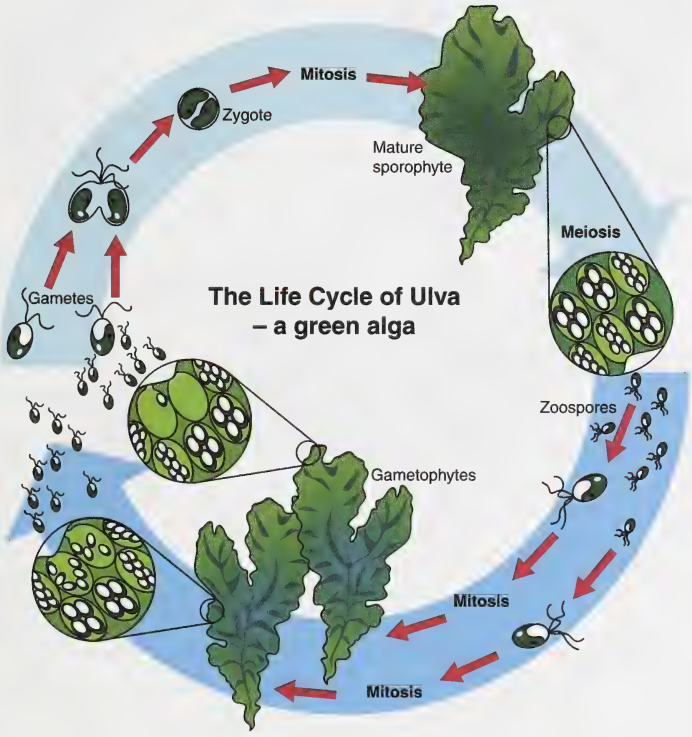
h. Does the zygote grow into a sporophyte or a gametophyte?

Check your work with the answers in the Appendix.

Self-Check

In this lesson you have learned about the diversity of reproductive strategies for a range of organisms. You can appreciate the variety of ways species balance their life cycles. To apply your understanding, complete the following questions.

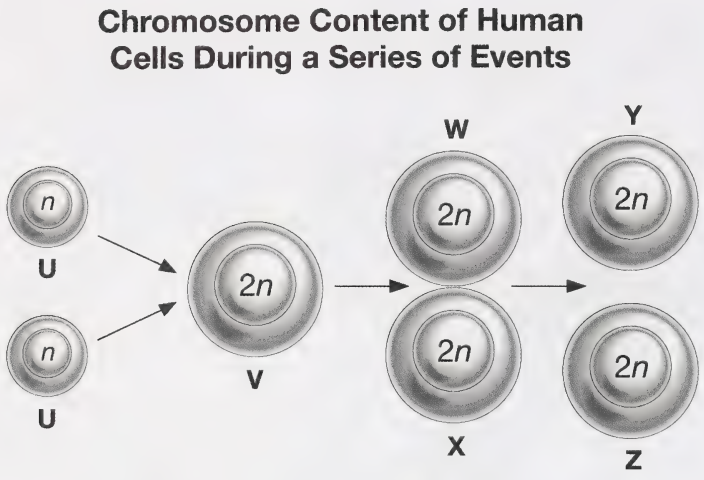
Use the following information to answer the next question.



SC 11. Which structures in the life cycle of Ulva are haploid (monoploid)?

A. zoospores and the zygote
B. the sporophyte and the zygote
C. zoospores and the gametophytes
D. the sporophyte and the gametophytes

Use the following information to answer the next two questions.



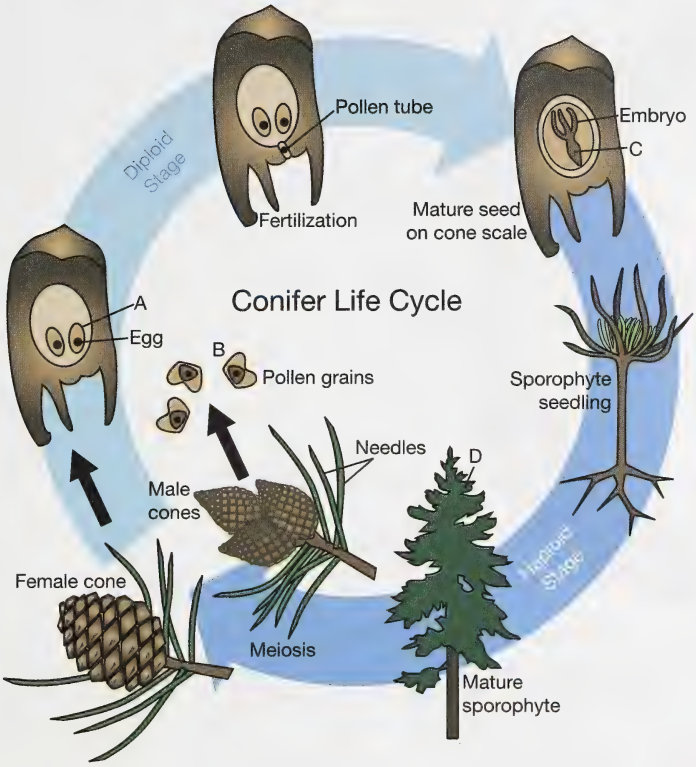
SC 12. In humans, what process must have occurred to obtain the cells at U?

A. mitosis
B. meiosis
C. fertilization
D. differentiation

SC 13. In humans, what process must occur before cell V forms cells W and X?

A. mitosis
B. meiosis
C. recombination
D. nondisjunction

Use the following information to answer the next question.



Numerical Response

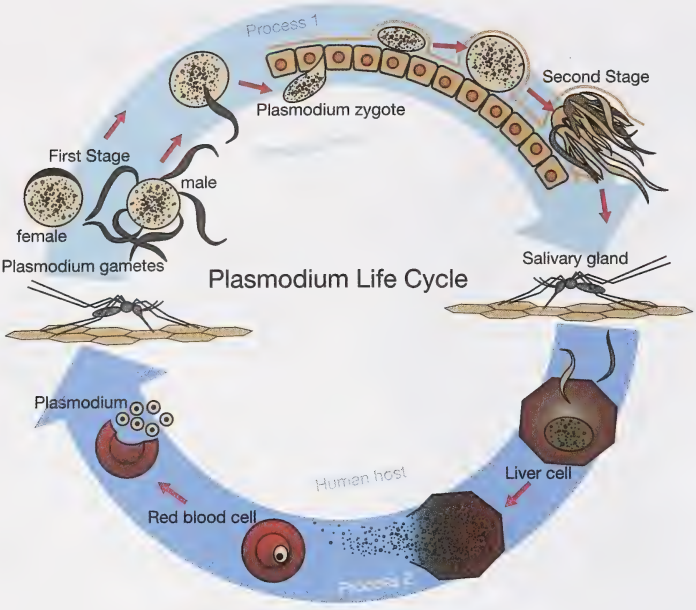
SC 14. Identify the stages in the conifer life cycle, as numbered below, that correspond with the letters that represent the stages on the diagram.

Stages in the Conifer Life Cycle

1. haploid stage
2. diploid stage

Stages:				
Diagram:	A	B	C	D

Use the following information to answer the next question.



SC 15. Identify the row in the table below that identifies the chromosome number at the first stage and the chromosome number at the second stage.

Row	First stage	Second stage
A.	diploid	haploid
B.	diploid	diploid
C.	haploid	diploid
D.	haploid	haploid

Check your work with the answers in the Appendix.

Reflect on the Big Picture

In this lesson you have looked at a variety of life cycles found in organisms. Each cycle balances the speed and ease of mitosis with the variety and change of meiosis. Earlier you learned how those processes result in cells for growth or gamete cells for reproduction. When you completed "Thought Lab 16.2: Comparing Reprodcutive Strategies" for the Lesson 6 Assignment, you conducted research on two organisms and their reproductive strategies. You related the processes of mitosis and meiosis to the various reproductive cycles of the different organisms of your choice.

The Module Assessment is described in the Module Summary and Assessment section. In the Module Assessment, you will examine normal growth, repair, and reproduction in cells and organisms. You will also look into exceptions to normal cellular patterns and evaluate their impact. You will again have an opportunity to apply the patterns you explored in this lesson to your work in responding to your choice of the options provided in the Module Assessment.

Module 5: Lesson 6 Assignment

Make sure you have completed all of the questions for the Lesson 6 Assignment. Check with your teacher about whether you should submit your assignment now or wait until all of the Module 5 assignments have been completed.

Lesson Summary

In this lesson the following focusing questions were examined

- What are the advantages or disadvantages of different reproductive strategies?
- Why do some organisms vary their reproductive strategies?

Organisms can reproduce quickly and effectively by way of mitosis and asexual reproduction. The resulting offspring may take over a habitat and the whole species will benefit by a sheer growth in numbers. However, the entire population will be genetically identical. They may all be susceptible to a virus or disease and experience rapid death.

To balance the need for high numbers of offspring and to reproduce quickly, many organisms include a part of their life cycle that requires meiosis and sexual reproduction. This increases genetic variability and allows for offspring that are different from their parents. Some of these organisms may not be susceptible to a disease or a change in the environment that hurts the general population. These organisms will live to reproduce again.

Some organisms alternate their strategies depending on conditions. This allows for the best of both reproductive worlds. When conditions are good, mitotic or asexual reproduction can quickly help colonize an area. However, when the conditions become unfavourable, meiosis or sexual reproduction will allow for genetic variation that will help the species survive.

Because this is the last lesson in this module, remember to submit the following items:

- Module 5: Lesson 6 Assignment
- Module 5 Assessment

Lesson Glossary

Consult the glossary in the textbook for other definitions that you may need to complete your work.

alternation of generations: a plant life cycle where two distinct multicellular forms of a sporophyte and a gametophyte occur in one generation

A diploid zygote undergoes mitosis to form a diploid sporophyte, which undergoes meiosis to form haploid unicell spores, each of which undergo mitosis to form a multicellular haploid gametophyte, which undergoes mitosis to form unicellular gametes, which fuse with other gametes to produce a diploid zygote. Animals do not display alternation of generations.

binary fission: asexual cell division in prokaryotes; replication of the circular chromosome and division of the DNA and cytoplasm without the use of a spindle; offspring are clones; rate is very rapid

budding: a type of asexual reproduction

In yeast, unequal cytokinesis in mitosis forms a large cell and a tiny cell that buds off; in Hydra, a small multicell mini-polyp breaks off and forms an adult.

conjugation: a type of sexual reproduction that occurs when two cells form a cytoplasm bridge through which they exchange genetic material, producing variation; occurs only in unfavourable environments

fragmentation: an asexual form of reproduction in animals similar to cutting in plants (e.g., a flatworm with tail cut off can regenerate the lost section)

gametophyte: a multicellular stage in alternation of generations that consists of haploid cells that split off to produce haploid gametes

life cycle: the stages an organism goes through to grow, reproduce, and die

parthenogenesis: a rare type of asexual reproduction; an unfertilized haploid egg divides by mitosis, producing a complete multicellular organism in which all cells are haploid; seen in amphibians, reptiles, and birds

prokaryotes: single-celled organisms without a nuclear membrane, such as bacteria; have one circular chromosome; divide asexually by binary fission and "sexually" by conjugation

spore: a haploid cell produced by meiosis in the sporophyte; each is capable of dividing to form a multicellular gametophyte consisting of haploid cells

sporophyte: the diploid multicellular stage in plants that show alternation of generations; produces haploid spores by meiosis

Module Summary

In this module you were asked the following inquiry question:

How do cellular processes allow for growth, healing, and reproduction in supporting the survival of organisms?

In this module you examined cell growth, repair, and reproduction. By understanding the life cycle of your cells, you gained insight into how your own body renews itself over the course of your lifetime. You have studied the differences between combatting the signs of aging and actually keeping your cells in a healthy cell cycle of growth and repair. You can better understand how cancer can lead to serious health concerns and how various treatments show promise in combating this disease. You have examined emerging technologies involved in cell research and are better prepared to help society guide scientists in setting limits or guidelines for new research aimed at combating serious illness and disease.

To review and summarize the concepts of this module, you may wish to complete a concept organizer or mind map. When you began your study of this module, you may have saved a copy of this document when you encountered it in the Introduction to the Big Picture section, or you may download it now from the multimedia DVD. It is an outline of the lessons, with the focusing questions for the lessons that you studied in this module. Use the focusing questions to fill in this framework with the ideas that you have mastered in each lesson and how these ideas help you answer the focusing questions. You can use keywords, point form, or any amount of detail that facilitates your needs. You may choose to work on your computer, to print the document and work from the hard copy, or to copy the outline onto a large poster-like sheet of paper to fill in your work. This is a great tool to review and to use for study purposes.

Before you begin the Module Assessment, you may choose to complete the review questions on pages 582 to 583 of your textbook for extra practice. Your teacher will help you with any questions that you might have and give you feedback on your responses.

Module Assessment

In this module you will examine normal growth, repair, and reproduction in cells and organisms. You will also look into exceptions to normal cellular patterns and evaluate their impact. When you have completed all of the lessons, you will need to complete one of the following Module Assessment tasks.

Choice 1

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You are a leading horse breeder, and you have recently invested in a prize-winning endurance performance stallion. You were looking forward to using him in your breeding program, but he developed testicular cancer and both of his testicles had to be removed. The loss is disastrous to your breeding program.

Not willing to give up, you begin investigating other ways you could carry on his genetics. You read about a sheep in England that has been cloned, and then you find a few other stories about livestock that have been successfully cloned. You decide you would like to try cloning, but you need to convince the other investors that this is a viable plan for developing horses for high-endurance racing.

Outline a proposal for how you intend to carry on the horse's genetics. In a flow chart and illustrations, outline in detail the steps involved and explain any technologies you will need to use. Also, create a long-range plan. Will you continue to produce foals this way, or will you try a different method? Explain your reasoning.

Choice 2

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In this module you saw examples of organisms that switch between sexual and asexual reproduction or use a method known as parthenogenesis. Choose one of these organisms that interests you or find another one that shows a unique alternating reproduction pattern. Create a short report or presentation introducing the organism. Explain its key adaptations and its usual habitat. In your work, include a flow chart with illustrations that explains each of the ways the organism reproduces and how these alternating cycles are related. Label where major events, such as mitosis, meiosis, and fertilization, take place in the life cycle. Also, discuss the reasons why the organism reproduces the way it does at each stage of its life cycle.

Choice 3

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You are working for Greenpeace. A concern has been brought to your attention involving the increasing die-off of trout in a local freshwater lake. You are looking into the possibility of the problem originating in the food chain. You discover that trout feed on a microscopic organism called *Daphnia*, and that the population size of *Daphnia* is rapidly declining. You also discover traces of a pesticide in the lake. You have traced this pesticide back to a local farmer who had sprayed the pesticide, which has now seeped through the groundwater into the lake. The pesticide works by preventing the duplication of chromosomes. You will need to present your findings to a council at a town hall meeting. Your presentation must include an illustration of a general cell life cycle and a *Daphnia* life cycle. In addition, your report or presentation should address the following issues:

- Where in the cell cycle would this pesticide cause a problem?
- Where in the *Daphnia* life cycle do mitosis, meiosis, and fertilization occur?
- With reference to the diagram:
  - discuss the roles and differences between mitosis and meiosis
  - explain the effect of fertilization
  - compare the consequences of pesticide exposure during the asexual phase and during the sexual phase of the *Daphnia* life cycle

Assessment Rubric for Students

Whichever assessment task you choose, you will be required to address four topics, each worth a total of 4 marks. Full marks will only be awarded when answers are complete and when correct biological vocabulary is used to present biological concepts. Each task has a total possible mark assessment of 16 marks. The topics choices are as follows:

Choice 1: Saving a Horse's Genetics

Cloning Flow Chart
Technologies
Long-Range Plans
Presentation Quality

Choice 2: Alternation of Generations or Parthenogenesis

Reproduction Flow Chart
Advantages and Disadvantages of Reproductive Processes
Adaptations and Habitat
Presentation Quality

Choice 3: Alternation of Generations or Parthenogenesis

Daphnia Life Cycle
Advantages and Disadvantages of Reproductive Processes
Consequences of Pesticide Exposure
Presentation Quality

Marking Rubrics for Module 5 Assessment

Choice 1: Saving a Horse's Genetics

	4 marks	3 marks	2 marks	1 marks	0 marks
Cloning Flow Chart	All steps are correct, labelled, and linked together in correct order using arrows, and/or symbols to create a proper flow chart.	Nuclear transplant from somatic cell to enucleated egg cell labelled and shown as a flow chart, but there are minor errors in the process.	All the steps are outlined or explained, but are not joined or outlined as a proper flow chart.	An attempt is made to illustrate cloning in a flow chart or to explain the process with words.	No clear indication is given that the student understands cloning.

Technologies	Surgical techniques to harvest cells, microscope guidance for nuclear transplant, application of electrical current to fuse nucleolus and stimulate cell division, and hormonal treatments to the surrogate mother for implantation are described.	Two of the four technologies are described.	One of the four technologies is described.	Procedures are discussed or technologies are implied.	There is no mention of technologies in the presentation.
Long-Range Plans	Plan explains how, upon birth of a male, breeding should revert back to normal means.	Plan mentions how, after cloning, the offspring can be used as breeding stock.	Plan explains how cloning could be continued for little cost.	Plan mentions cloning will be continued.	No mention of a long-range plan is given.
Presentation Quality	Presentation is clear, organized, and creative.	Presentation is clear and organized.	Presentation is understandable.	Presentation is not clear or not organized.	Presentation is not clear and is disorganized.

Choice 2: Alternation of Generations or Parthenogenesis

	4 marks	3 marks	2 marks	1 marks	0 marks
Reproduction Flow Chart	All steps are correct, labelled, and linked together in correct order using arrows, and/ or symbols to create a proper flow chart.	Different stages in the life cycle are clearly identified, and mitosis and meiosis are correctly indicated.	Different stages in the life cycle are clearly identified, and mitosis or meiosis are correctly indicated or ploidy count is correctly given.	An attempt is given that illustrates a reproductive cycle.	No clear indication is given that the student understands a reproductive cycle.
Advantages and Disadvantages of Reproductive Processes	A and D of meiosis, fertilization, and mitosis are correctly explained in context of this organism.	A and D of meiosis, fertilization, and mitosis are correctly explained.	Some of the A and D of meiosis, fertilization, and mitosis are listed.	Some of the A and D of meiosis and fertilization, or mitosis are listed.	No mention of advantages or disadvantages are given.
Adaptations and Habitat	Three adaptations and how they support the organism in its habitat are explained.	Three or more adaptations are listed, and the habitat is outlined.	Two adaptations are listed, and the habitat is outlined.	One adaptation is listed or the habitat is outlined.	Nothing is given about adaptations or habitat.
Presentation Quality	Presentation is clear, organized, and creative.	Presentation is clear and organized.	Presentation is understandable.	Presentation is not clear or not organized.	Presentation is not clear and is disorganized.

Choice 3: Alternation of Generations or Parthenogenesis

	4 marks	3 marks	2 marks	1 marks	0 marks
***Daphnia* Life Cycle**	All steps are correct, labelled, and linked together in correct order using arrows, and/ or symbols to create a proper flow chart.	Different stages in the life cycle are clearly identified, and mitosis and meiosis are correctly indicated.	Different stages in the life cycle are clearly identified, and mitosis or meiosis are correctly indicated or ploidy count is correctly given.	An attempt is given that illustrates a reproductive cycle.	No clear indication is given that the student understands a reproductive cycle.
Advantages and Disadvantages of Reproductive Processes	A and D of meiosis, fertilization, and mitosis are correctly explained in context of this organism.	A and D of meiosis, fertilization, and mitosis are correctly explained.	Some of the A and D of meiosis, fertilization, and mitosis are listed.	Some of the A and D of meiosis, fertilization, or mitosis are listed.	No mention of advantages or disadvantages are given.
Consequences of Pesticide Exposure	Effects on both meiosis and mitosis are explained and compared with each other.	Effects on both meiosis and mitosis are explained.	Effects on either meiosis or mitosis are explained.	Effects for either meiosis or mitosis are listed.	Nothing is given about adaptations or habitat.
Presentation Quality	Presentation is clear, organized, and creative.	Presentation is clear and organized.	Presentation is understandable.	Presentation is not clear or not organized.	Presentation is not clear and is disorganized.

Module 5 Glossary

Consult the glossary in the textbook for other definitions that you may need to complete your work.

2*n*: the symbol referring to a diploid cell

alleles: different versions (base sequences) of a gene or trait that will code for slightly different proteins (e.g., sickle cell hemoglobin versus normal hemoglobin)

Increased types of alleles in the gene pool increases variation and diversity and protects the species from extinction.

alternation of generations: a plant life cycle where two distinct multicellular forms of a sporophyte and a gametophyte occur in one generation

A diploid zygote undergoes mitosis to form a diploid sporophyte, which undergoes meiosis to form haploid unicell spores, each of which undergo mitosis to form a multicellular haploid gametophyte, which undergoes mitosis to form unicellular gametes, which fuse with other gametes to produce a diploid zygote. Animals do not display alternation of generations.

amniocentesis: a needle sampling of fetal amniotic fluid to gather embryonic cells for karyotyping; determines chromosome number and gender, not presence of specific genes/alleles on chromosomes

anaphase: the third phase of mitosis where spindle fibres contract, pulling sister chromatids of each chromosome apart to opposite poles

anchorage dependence: a property of normal cells that only allows mitosis to occur when cells are attached to a substrate or surface, not floating freely

Anchorage dependence is lost in cancer, thereby allowing for metastasis to occur.

asexual reproduction: creation of a new organism without the input of cells from two separate organisms of opposite sexes; examples are binary fission, yeast and Hydra budding, and vegetative propagation of plants

autosomes: the 22 homologous pairs seen in a karyotype; have nothing to do with gender

binary fission: cell division in prokaryotes (bacteria); simple because there is only one circular chromosome so no spindle is needed

binary fission: asexual cell division in prokaryotes; replication of the circular chromosome and division of the DNA and cytoplasm without the use of a spindle; offspring are clones; rate is very rapid

blastocyst: the embryonic stage about one week after conception; a hollow ball of cells consisting of outer trophoblast that becomes the chorion and inner cell mass that becomes the embryo; implants in the wall of the endometrium

budding: a type of asexual reproduction

In yeast, unequal cytokinesis in mitosis forms a large cell and a tiny cell that buds off; in Hydra, a small multicell mini-polyp breaks off and forms an adult.

cancer: rapid proliferation (cell division) of cells that occurs when mutations result in disruption of the normal timing of mitosis; characterized by loss of density-dependent inhibition, loss of anchorage dependence, dedifferentiation of cell function, rapid metabolism, and short cell cycle

cell cycle: the period of time between one cell division and the next; consists of interphase, mitosis, and cytokinesis; may also be divided into interphase and M phase (mitosis and cytokinesis)

cell division: the period of the cell cycle where the cell is actively dividing; composed of mitosis and cytokinesis stages

cellular clock: a property of cells that allows them to go through a set number of cell divisions and then stop, whereupon the cell line dies out; sometimes called apoptosis

Cancer cells do not have a normal cell clock so they do not apoptose.

centrioles: organizing bodies of the spindle

As they move apart in prophase, spindle fibres stretch out between them, forming the spindle apparatus.

centromere: a 'button' that keeps the two identical sister chromatids together after the S phase of interphase and through mitosis until anaphase

chemotherapy: the use of cytotoxic drugs that inhibit cell division, usually by preventing DNA replication or interfering with the spindle mechanism of mitosis or by interfering with the supply of blood and nutrients to the tumour; applied systemically (into the bloodstream); targets cancerous cells but may also affect rapidly dividing normal cells to some degree

chorionic villus sampling (CVS): a sampling of chorionic villi through the vagina, used to obtain embryonic cells for karyotyping

chromatid: one-half or one of two threadlike strands into which a chromosome divides during cell division

chromatin: long fibres containing DNA, small amounts of RNA, and proteins

These fibres form chromosomes when they coil around histones.

chromosome: a thick, rod-shaped body in the nucleus that forms when chromatin (long, stringy DNA) supercoils around balls of histone proteins in prophase of mitosis and meiosis

clone: to create of an exact replica

A cell is a clone if it is the product of asexual reproduction (mitosis or binary fission) that produces two genetically identical cells. An organism can be a clone if it is genetically identical to another organism (e.g., animals can be cloned by taking a nucleus from one animal and inserting it into an empty egg of another, producing an offspring identical to the one that donated the nucleus). Cloning is used in agriculture and pharmaceutical industries to create uniform, consistent products.

conjugation: a type of sexual reproduction that occurs when two cells form a cytoplasm bridge through which they exchange genetic material, producing variation; occurs only in unfavourable environments

cordiocentesis: a sampling of umbilical cord blood of fetus for karyotyping

crossing over: an occurance during meiosis I when homologous pairs and their attached sister-chromatids form tetrads, entwine in synapsis, and may be chopped by enzymes into pieces

When chromosomes are reassembled, sections of the mother's homologue may be exchanged with the father's, forming chromosomes with new combinations of mother's and father's alleles. This increases variation in gametes and offspring, improving the species' chances of survival if the environment changes.

cutting: type of vegetative propagation when a stem of a plant is cut off and produces roots, stems, leaves, and flowers; an asexual form of reproduction

cytokinesis: the phase of the cell cycle after mitosis when the cytoplasm divides into two separate daughter cells

A cleavage furrow forms in animal cells; a division plate forms in plant cells.

daughter cell: a cell that is the product of cell division

In mitosis, daughter cells are identical to the mother cell; in meiosis, they are not identical to the parent cell.

density-dependent inhibition: a property of normal cells that allows mitosis to occur only until cells touch each other

Density-dependent inhibition is lost in cancer cells; therefore, cells begin to form on top of one another, forming masses of cells called tumours.

diploid: the chromosome number of a somatic (body) cell; both chromosomes of each homologous pair are present; two sets of chromosomes are present, one from each parent

DNA: the genetic material found contained in the nucleus in eukaryotes (also in mitochondria and chloroplasts) and loose in the cytoplasm in prokaryotes, such as bacteria

Down syndrome: typically characterized by some impairment of physical growth, unique physical features, and below average cognitive ability

If an $n + 1$ gamete that results from nondisjunction of a twenty-first chromosome is fertilized by a normal sperm, a Trisomy 21 ($2n + 1$) offspring is produced with Down syndrome.

eukaryotic cell: a cell with membrane-bound organelles and nucleus

fertilization: fusion of an egg and sperm (gametes) to produce a zygote; occurs in sexual reproduction only

fragmentation: an asexual form of reproduction in animals similar to cutting in plants (e.g., a flatworm with tail cut off can regenerate the lost section)

fraternal twins: two siblings born at the same time, resulting from the accidental ovulation of two eggs, which are fertilized by two sperm

Fraternal twins are as different as any two siblings.

G1 phase: the first part of interphase where the cell is actively growing and undergoing metabolism and protein synthesis

G2 phase: the third part of interphase where the cell continues growing, metabolizing, and carrying out protein synthesis

gametes: sex cells (sperm and egg); have half the normal chromosome number so they can participate in fertilization

gametophyte: a multicellular stage in alternation of generations that consists of haploid cells that split off to produce haploid gametes

gene: the unit of hereditary information that can be passed on to offspring; includes the specific DNA sequence encoding or regulating the sequence of a protein, tRNA, or rRNA molecule; determines the expression of a trait

genetic material: DNA; contains the genes that direct the synthesis of proteins needed by the cell; exists as chromatin or chromosomes

genetic variation: the permutations and combinations of genes and alleles possible; refers to different combinations of mother's and father's alleles in gametes; increases variation in the offspring and translates into better odds of offspring survival in changing environments

haploid: the term describing a cell containing half the chromosomes that a diploid parent cell contains

This condition occurs in gametes, either in the egg or the sperm.

haploid: chromosome number of a gamete (sex cell—egg or sperm), resulting from meiosis; only one chromosome of each homologous pair is present; one set of chromosomes present

histones: proteins found in chromosomes that provide scaffolding for DNA to twine around so that the DNA can fit within the confined space of the nucleus

Hodgkin's disease: a blood cancer of lymph tissue

identical twins: result of one egg fertilized by one sperm; occurs when the morula splits into two masses that develop independently in the uterus; offspring are genetically identical

independent assortment: one of Mendel's Laws of heredity

There are two uses of this term:(1) In meiosis I, tetrads line up randomly on the metaphase plate so that either the mother's or the father's sister chromatids are on one side. When all the tetrads are pulled apart in anaphase I, the chromosomes that collect at each pole are a unique combination/permutation of mother's and father's chromosomes/alleles. The orientation of one tetrad is independent of the others. (2) in reference to whether or not two genes are on the same chromosome or on different ones: If on different chromosomes, one gene (allele) is independent of the other gene in the way their tetrad lines up on the metaphase plate of meiosis I, and much gamete variation can result. If genes are linked on the same chromosome, the two genes cannot line up independently of each other—they are tied together, limiting the variety of permutations/ combinations and variation in gametes that can be formed.

interphase: the longest period of the cell cycle when the cell is actively growing and metabolizing; consists of G1, S, and G2 phases; DNA is in loose, stringy chromatin form not visible under the microscope

karyotype: a pictorial representation of all the chromosomes of a cell arranged in homologous pairs according to size, centromere position, and banding pattern; used to diagnose abnormalities in chromosome number (non-disjunction) and to determine sex chromosomes

kinetochore: another word for centromere; the small body holding the sister chromatids together as one chromosome; attaches to a spindle fibre at the metaphase plate

Klinefelter syndrome: born with primary male sex characteristics but develops female secondary sex characteristics

When an XX egg due to nondisjunction is fertilized by a Y sperm, the offspring (XXY) has Klinefelter syndrome.

life cycle: the stages an organism goes through to grow, reproduce, and die

locus: a specific location on a chromosome

meiosis: cell division that results in cells that have half the normal chromosome number (haploid gametes); also called reduction division

meiosis I: the first division of meiosis; preceded by DNA replication in interphase; results in one secondary oocyte and first polar body in females and two secondary spermatocytes in males

Because homologous pairs are separated from each other in anaphase, cell products are already considered haploid.

meiosis II: the second division of meiosis; no DNA replication in interphase; results in one haploid ootid and second polar body in females and four haploid spermatids in males

metaphase: the second phase of mitosis where chromosomes line up on the equator (metaphase plate) and attach via their centromeres to a spindle fibre

Each centromere replicates so each sister chromatid has its own to allow spindle fibre to attach.

metastasis: the tendency of some cancer cells to break off from a primary tumour and move through the blood or lymphatic systems to other locations in the body where secondary tumours form; sometimes referred to as the "spreading" of cancer

mitosis: cell division that results in identical cells; used for growth and repair of organisms

monosomy: offspring that only have one of a particular chromosome rather than two; occurs when a normal n gamete fuses with an $n - 1$ gamete, producing a $2n - 1$ zygote; in humans, an offspring that has a diploid number of 45 rather than 46

M phase: mitosis and cytokinesis together

mutagenic agent: a chemical or physical agent that has the ability to mutate DNA, affecting the timing of the cell cycle; increasing the rate of mitosis

mutation: a permanent change in a cell's genetic structure, often resulting in the expression of a new trait or feature in the affected organism; usually due to random errors occurring during DNA replication or protein synthesis, but can also be caused by chemical or physical mutagens

***n*:** symbol referring to a haploid cell

nondisjunction: an error in meiosis that results in non-separation of chromosomes; results in two chromosomes entering one gamete; produces gametes with an extra chromosome ($n + 1$), or gametes that are missing a chromosome ($n - 1$)

nondisjunction: non-separation of chromosomes during meiosis; one pair gets dragged to one pole, and no representative of that pair is pulled to the other pole; if occurs in meiosis I, gametes will be two $n + 1$ gametes and two $n - 1$ gametes; if occurs in meiosis II, gametes will be $n + 1$, $n - 1$, n, and n, results in offspring that have a trisomy or monosomy for that chromosome

oocyte: a cell undergoing oogenesis

The primary oocyte undergoes meiosis I, producing a large secondary oocyte and the first polar body, which is reabsorbed. The secondary oocyte undergoes meiosis II, forming a large ootid and a second polar body, which is reabsorbed.

parent cell: a diploid somatic cell about to enter cell division

parthenogenesis: a rare type of asexual reproduction; an unfertilized haploid egg divides by mitosis, producing a complete multicellular organism in which all cells are haploid; seen in amphibians, reptiles, and birds

ploidy: refers to the chromosome number of a cell or how many sets of chromosomes are present; haploid cells have one set, diploid two, tetraploid four, octoploid eight

polar body: a tiny cell that results from each division of oogenesis

Meiosis I results in large secondary oocyte and a tiny polar body that is reabsorbed. Meiosis I results in a huge ootid and a tiny second polar body that is reabsorbed. Polar bodies are "garbage cans" that extra nuclear material is dumped into to fulfill the need for one large haploid ovum.

polyploid: the term describing a cell that contains more than two homologous chromosomes

prenatal genetic testing: sampling and testing of embryonic or fetal cells to determine chromosome number and gender

prokaryotes: single-celled organisms without a nuclear membrane, such as bacteria; have one circular chromosome; divide asexually by binary fission and "sexually" by conjugation

prophase: the first phase of mitosis where visible chromosomes appear scattered through a cell; nuclear membrane dissolves; centrioles move to opposite poles, forming a spindle between them

radiation treatment: cancer treatment in which high-energy radiation from radioactive isotopes is directed at a cancerous tumour in an effort to destroy it without destroying surrounding normal tissue

replication: the copying of the cell's DNA prior to mitosis so that each daughter cell has an exact copy of the mother cell's genetic material; results in sister chromatids; occurs in the S phase of interphase

resistance: occurs when a drug removes susceptible bacteria or viruses from a population and leaves those variants (mutants) that are resistant to the drug

Rapid cell division ensures that the whole population becomes resistant quickly.

sex chromosomes: the last (twenty-third) pair of chromosomes seen in a karyotype that determines the gender of an organism

X and Y sex chromosomes are not homologous to each other in terms of shape, size, or genetic information.

sexual reproduction: creation of offspring through input of genetic material from two different organisms of opposite sexes (sperm from male and egg from female); increases variation

sister chromatids: two pieces of DNA that are identical to each other as a result of DNA replication in S phase; lie side-by-side and are buttoned together by a centromere; together make up one chromosome

somatic cell: the name given to any of the cells of a multicellular organism, including humans

The exception is those cells that form gametes, which are not somatic cells.

spermatids: haploid cells that result from meiosis; swim to epididymis for maturation to a spermatazoan and storage until ejaculation

spermatocyte: cells undergoing spermatogenesis; primary spermatocyte undergoes first meiotic division, forming two secondary spermatocytes; each secondary spermatocyte undergoes second meiotic division, forming two spermatids; four spermatids formed from one primary spermatocyte

spermatogenesis: the process of producing gametes in males; occurs in walls of seminiferous tubules of testes

spermatogonium: initial diploid germ cell in spermatogenesis; undergoes mitosis, forming many primary spermatocytes that each carry out meiosis

S phase: the second part of interphase where DNA replication occurs in preparation for upcoming mitosis; produces sister chromatids

spindle apparatus: a structure composed of spindle fibres; forms during prophase in mitosis to facilitate separation and movement of chromosomes in cell division

spore: a haploid cell produced by meiosis in the sporophyte; each is capable of dividing to form a multicellular gametophyte consisting of haploid cells

sporophyte: the diploid multicellular stage in plants that show alternation of generations; produces haploid spores by meiosis

staining: a technique used in slide preparation to make the chromosomes of a dividing cell visible and dark

stem cell: an undifferentiated "generic" cell that can be coaxed into producing a number of different kinds of cells; present in embryonic blastocysts and also recently found in adults; potentially used to repair tissue and build replacement organs

Embryonic stem cell research is controversial due to the fact that the creation and termination of human blastocysts is used as a method of obtaining stem cells.

super bugs: bacteria that are immune to many antibiotics

Super bugs develop because of an overuse of antibiotics and antibacterials that have destroyed susceptible bacteria, leaving only those bacteria that are resistant to these drugs.

synapsis: the entwining of the homologous pair and attached sister chromatids in prophase I of meiosis; crossing-over between non-sister chromatids may occur

telomere: a section on each end of a chromosome that shortens with each mitotic division

If the telomere is too short, the cell no longer divides.

telophase: the fourth phase of mitosis where nuclear membranes form around the two groups of chromosomes; spindle apparatus dissolves; chromosomes decondense to become chromatin

tetrad: formed in prophase of meiosis I when homologous pairs and their attached sister chromatids find each other and entwine in synapsis; may undergo crossing-over with non-sister chromatids, increasing variation in the gametes that result

totipotent: cells that have not specialized or differentiated (e.g., zygote, morula); all genes in the cell have the potential to be expressed (turned on)

Totipotent cells have the ability to form a complete organism.

trisomy: offspring that have three of one kind of chromosome rather than two; occurs when an $n + 1$ gamete fuses with a normal n gamete, producing a $2n + 1$ zygote; in humans an offspring that has a diploid number of 47 rather than 46

variation: the existence of many combinations of genes/traits in a population; improves the probability that some members will survive if environmental conditions change; is high in sexual reproduction

X chromosome: the longer sex chromosome

Females are XX.

Y chromosome: the shorter sex chromosome; determines maleness; has much fewer genes on it than the X

Males are XY.

Appendix

Module 5: Lesson 1

Self-Check Answers

SC 1. Cell division is essential for repair (healing, the replacement of worn-out cells), for maintaining the life functions of the cells, and for the growth of new cells.

SC 2. Binary fission is a form of asexual reproduction among unicellular organisms, such as bacteria, that leads to an increase in the number of organisms. Mitosis is the division of one cell to create two new daughter cells within an organism. It yields more cells, but does not increase the number of organisms.

SC 3. Meiosis creates variation in the population. This enables a population to better withstand a changing environment.

SC 4. Chromosomes are condensed strands of DNA that are visible during cellular division. Chromatids are copies of chromosomes existing as single strands of doubled chromosomes still attached at the centromere. Chromatin refers to all the invisible uncondensed strands of chromosomes in a nucleus.

SC 5. Homologous chromosomes contain the same type of genetic information or genes (but not the exact same form or alleles). They are the same size and shape and, when stained, have the same banding pattern and placement of the centromere.

SC 6. A karyotype clearly displays the number and type of chromosomes present. From this, scientists can diagnose many major syndromes like Down syndrome, which is caused by an extra chromosome 21. They can also determine gender: XX for female, XY for male.

Module 5: Lesson 3

Self-Check Answers

SC 1.

a. mother cell in S phase of interphase
b. prophase
c. metaphase
d. anaphase
e. telophase
f. daughter cells following cytokinesis

SC 2.

a. There would be 48 chromosomes in nerve and bone cells.
b. There would be 48 chromosomes in each daughter cell.

SC 3. Centrioles provide attachment for spindle fibres and form the points to which chromatids are pulled during anaphase.

SC 4.

a. A
b. A
c. B
d. B
e. B
f. C
g. D
h. E

SC 5. Division of the cytoplasm is called cytokinesis. In animal cells, the cytoplasm pinches off, separating the two daughter cells. In plant cells, a new cell wall must form between the two nuclei because the existing cell walls are rigid and do not allow for pinching. The new cell wall is called a cell plate.

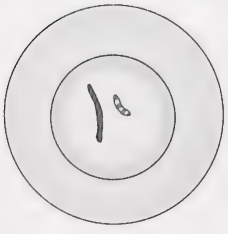
Module 5: Lesson 5

Self-Check Answers

SC 1.

a. One pair of homologous chromosomes did not separate, but instead the entire tetrad was pulled to one pole. This process is called nondisjunction.

b. A normal gamete would look like the cell below.



SC 2. Three genetic disorders are Down syndrome, Klinefelter syndrome, and Turner syndrome. There are many others.

SC 3.

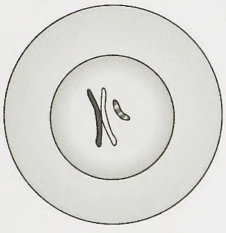
a. Nondisjunction has occurred in division I.

b. The egg cell shown has one too many chromosomes.

c. Yes, it would be abnormal, because it would lack one of the chromosomes that make up the set of 23. It would be lacking some of the genetic information needed for the potential offspring to develop normally.

SC 4. Monosomy is a condition in which only one chromosome of a particular type occurs instead of the usual pair.

Only one of these should be present.



Trisomy is a condition in which three copies of a particular chromosome occur instead of the usual pair.

SC 5. Situation A represents trisomy. Situation B represents monosomy.

SC 6.

a. trisomy female

b. Turner syndrome

c. Klinefelter syndrome

d. Turner syndrome

SC 7. The sex of the person is male because the presence of the Y chromosome produces maleness regardless of the number of X chromosomes present.

Module 5: Lesson 6

Self-Check Answers

SC 1. Budding involves mitosis because the bud is genetically identical to the original cell.

SC 2. Four ascospores are produced. This is consistent with the results of meiosis because four cells are produced by this process.

SC 3. Part A is the asexual phase and Part B is the sexual phase.

SC 4. Unsuitable conditions appear to trigger sexual reproduction.

SC 5. Mitosis is involved in production of gametes because the cells of the plant are already haploid, so meiosis cannot occur, nor does it need to.

SC 6. Meiosis occurs in the capsule of the sporophyte, producing haploid spores.

SC 7. The sperm must swim to the egg through a film of water.

SC 8. Spores are resistant to dryness and can survive harsh conditions during dispersal.

SC 9. The dominant stage is haploid.

SC 10.

a. sporophyte
b. diploid
c. spores
d. meiosis
e. haploid
f. gametophyte
g. gametes
h. sporophyte

While many of the strategies you've looked at may seem unusual, each has been developed by a species to gain advantage over other species. Balancing concerns over variation and speed, they generally alternate between mitosis for colonization and meiosis to overcome harsh conditions.

SC 11. C

SC 12. B

SC 13. A

SC 14. 1, 1, 2, 2

SC 15. C

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